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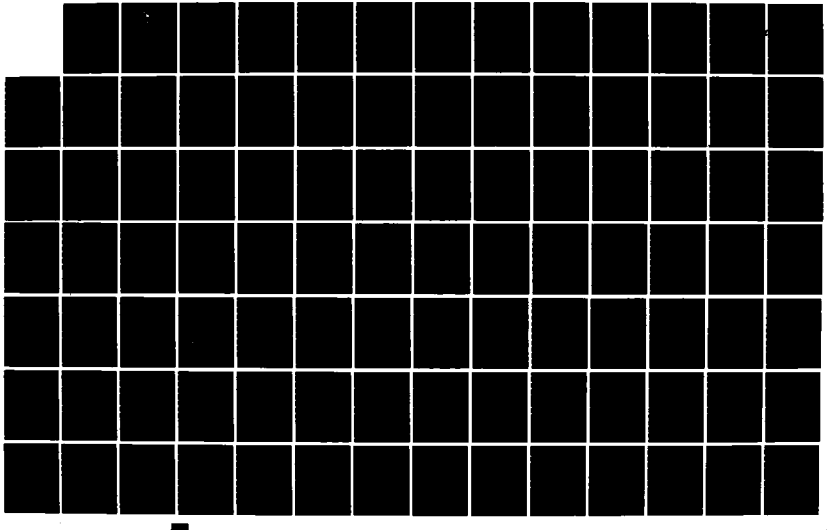

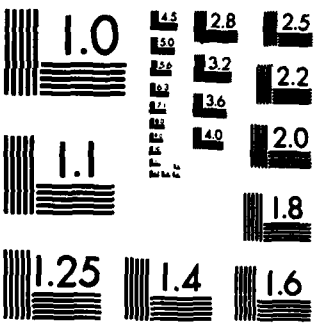
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EVALUATION OF EFFICIENCY/EFFECTIVENESS

THESIS

Timothy A. Byers, 1st Lieutenant, USAF
Susanne M. Waylett, Major, USAF

AFIT/GEM/LSM/84S-4

DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY
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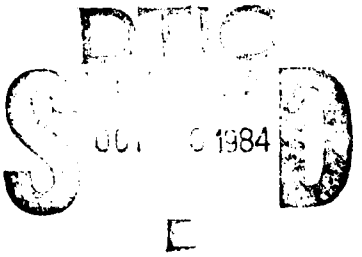

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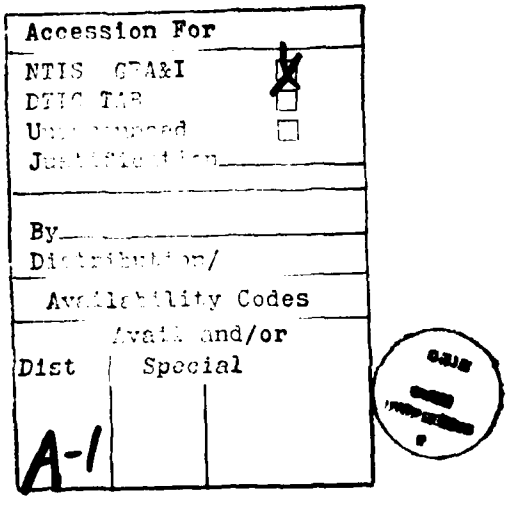

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The Air Force Engineering and Services Center, in conjunction with their efforts to develop a performance work statement and performance measurement for each Civil Engineering function, sponsored this research to develop a method of evaluating the productivity of Air Force Fire Departments. Using the tasks developed by the Fire Department Workshop, input and output measures were defined and used in a new model of efficiency called Constrained Facet Analysis (CFA). The advantage of this methodology over others considered was that it can simultaneously evaluate multiple inputs and multiple outputs using empirical data with no "a priori" weighting. The results of the analysis provided an efficiency rating for each fire department and information about marginal rates of substitution and marginal rates of productivity for inefficient units based on their efficiency frontiers. Though the current CFA model has some dimensioning limitations that affected the depth of analysis available, the resulting evaluations gave a better indication of the real efficiency of individual fire departments than methods currently used and also gave better comparative information to be used in budgeting and resource allocation decisions. The CFA model continues to evolve and this research validates its value to the Air Force. Further research both in Constrained Facet Analysis and its application to other Civil Engineering functions is warranted.

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MEASUREMENT OF AIR FORCE FIRE DEPARTMENT PRODUCTIVITY: AN EVALUATION OF EFFICIENCY/EFFECTIVENESS

THESIS

Presented to the Faculty of the School of Systems and Logistics
of the Air Force Institute of Technology
Air University
In Partial Fulfillment of the
Requirements for the Degree of
Master of Science in Engineering Management

Timothy A. Byers, B.S.C.E.
First Lieutenant, USAF

Susanne M. Waylett, B.S.E.
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September 1984

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Abstract

The Air Force Engineering and Services Center, in conjunction with their efforts to develop a performance work statement and performance measurement for each Civil Engineering function, sponsored this research to develop a method of evaluating the productivity of Air Force Fire Departments. Using the tasks developed by the Fire Department Workshop, input and output measures were defined and used in a new model of efficiency called Constrained Facet Analysis (CFA). The advantage of this methodology over others considered was that it can simultaneously evaluate multiple inputs and multiple outputs using empirical data with no "a priori" weighting. The results of the analysis provided an efficiency rating for each fire department and information about marginal rates of substitution and marginal rates of productivity for inefficient units based on their efficiency frontiers. Though the current CFA model has some dimensioning limitations that affected the depth of analysis available, the resulting evaluations gave a better indication of the real efficiency of individual fire departments than methods currently used and also gave better comparative information to be used in budgeting and resource allocation decisions.

The CFA model continues to evolve and this research validates its value to the Air Force. Further research both in Constrained Facet Analysis and its application to other Civil Engineering functions is warranted.

MEASUREMENT OF AIR FORCE FIRE DEPARTMENT PRODUCTIVITY: AN EVALUATION OF EFFICIENCY/EFFECTIVENESS

I. Introduction

Background

Interest in improving efficiencies within the Department of Defense (DOD) was reasserted in response to a Reagan Administration program. The application of the Office of Management and Budget (OMB) Circular A-76, contracting to a commercial source, had already effected an increase in the efficiency of many functions by requiring that they compete against contractors. The thrust of the new program, then, was aimed at the functions exempt from application of the circular and the objective of the program was to achieve like increases in the efficiencies of these functions. The program directed within the Air Force is called the Air Force Functional Review Program. It requires all functions to prepare a Performance Work Statement and a Quality Assurance Plan to promote efficiency and effectiveness (1:2-8).

The Air Force Engineering and Services Center (AFESC) was tasked by Major General Clifton D. Wright, Director of Engineering and Services, HQ USAF, to be the Office of Primary Responsibility for the functional review for Engineering and Services. They approached the review as an

opportunity to improve management and productivity and named the program Project "IMAGE" (Innovative Management Achieves Greater Effectiveness). Project "IMAGE" began by concentrating on the Fire Department, one of the most difficult organizations to evaluate.

Problem Statement

The AFESC Fire Department functional review workshop was completed on 30 June 1983. The performance work statement and quality assurance plan for this function were developed and generally accepted by Fire Department representatives present at the workshop (attendance list is contained in Appendix A). However, even though inputs and an exhaustive list of tasks shown in Appendix B were identified for each function within the Fire Protection Branch (Technical Services, Operations and Management), the group did not agree on common outputs, nor did they identify a model which could adequately guide them to more efficient operations.

Research Objectives

With the sponsorship of the Management Division and the cooperation of the Fire Protection Group of the Engineering and Services Center, this research will use the measurement criteria developed at the Fire Department functional review workshop to address the following objectives:

1) To collect historical data on the measures of Air Force Fire Department inputs and outputs that are thought to be likely ingredients of or influences on Civil Engineering Fire Department productivity; and

2) To analyze this data using the Constrained Facet Analysis model to determine whether or how each data item relates to productivity.

3) To theorize how Constrained Facet Analysis can be integrated into an automated management system to assist the Fire Chief in evaluating both efficiency and effectiveness of his Fire Department.

Research Questions

In support of these objectives, four research questions must be answered:

1) Can a comprehensive set of inputs and outputs be specified to form a complete representation of Air Force Fire Department functions?

2) After reviewing the ratio analysis, linear regression, Data Envelopment Analysis, and Constrained Facet Analysis models, does the Constrained Facet Analysis model provide the best efficiency model for analyzing this data?

3) Do analysis results lead to recommendations for operational improvements?

4) How can each level of management best use the results of this analysis to improve efficiency and effectiveness?

Scope, Limitations and Definitions

This research will evaluate the productivity of Air Force Fire Departments using a definition of productivity which is a combination of efficiency and effectiveness concepts. DODI-5010.34 provides definitions of productivity, effectiveness, and efficiency for use within the Department of Defense (DOD).

> Productivity: The efficiency with which organizations utilize all types of fund resources (operating and investment) to accomplish their mission represents total resource productivity. The efficiency with which organizations utilize labor resources to accomplish their missions represents labor productivity [26:1].
>
> Efficiency: Efficient means accomplishing the right things with the lowest possible expenditure of resources [26:1].
>
> Effectiveness: Effectiveness means accomplishing the right things in the right quantities, at the right times [26:1].

These definitions overlap to some degree which might be confusing to the reader; therefore, the following definitions are offered to help clarify these concepts:

> Productivity: a combination of efficiency and effectiveness.
>
> Efficiency: producing the greatest results with minimum waste of resources (Output/Input).
>
> Effectiveness: the ability to attain the goals of the organization.

The method of evaluating productivity will be to first quantitatively measure the efficiency of a Fire Department. Then Fire Protection experts will use their own expertise and judgement, guided by applicable Air Force regulations,

to determine the effectiveness of the unit. The productivity of the unit will thus reflect both the ability to perform the mission and the ability to best utilize available resources to do so.

Limitations and assumptions applied to the project are:

1) The basic goal of Fire Protection is to protect life and property and, in Air Force Fire Protection, to support the flying mission. This goal will not be compromised; effectiveness must have higher priority than efficiency.

2) The Fire Department is a part of the Civil Engineering organization and, as such, must be concerned with budget and personnel constraints applied to Engineering and Services.

3) In the fiscal climate of the DOD in the 1980's, resources are limited and every organization must evaluate how to best use the available resources to accomplish the mission.

4) The decision making unit for the evaluation is a base level Fire Department, though the Major Commands will use the results for their decisionmaking as well.

5) The database will be limited to those Continential United States (CONUS) bases which operate using an in-service work force, not including Air Force Reserve units.

6) All operations firefighters work a 72 hour work week and Fire Departments are manned at a constant rate high

enough that total authorized versus assigned manning is not a factor affecting efficiency.

7) The results of this research may be used by Engineering and Services to improve productivity, but not to penalize or threaten the managers and organizations involved.

II. Literature Review

To appreciate the complexity of the problem that the research addresses, a review of the literature in two topic areas is necessary. An examination of the results of research in the area of public sector fire service productivity and of how productivity has been addressed in government (particularly the Department of Defense and the Air Force) will be presented in this chapter.

Productivity in Fire Service

Controversy over the definition of productivity and its relationship to efficiency and effectiveness extends into public service agencies, including the Fire Service. The need for some type of measurement and the lack of identifiable methods is evidenced in the literature.

Charles P. Shannon, in his article entitled "Fire Service Administrators Find New Tools to Measure Performance," includes two comments on reasons for the current emphasis on productivity. "As professional and political demands for performance accountability accelerate, the need for statistically measureable performance criteria will become essential to fire administrators " (33:52). Furthermore, "fire service administrators are now expected to know what their citizens are getting for their tax money and be able to demonstrate these facts to others" (33:52).

"Every good chief would like to know what composition of forces and what total resources will minimize the overall cost to the citizen while fulfilling his responsibility for fire protection" (32:iv-v). The foregoing statement by John T. O'Hagen, Fire Commissioner, Fire Department, City of New York, describes the general feeling of responsibility within the Fire Service. Other experts in the field have agreed:

> The fire service mission is traditional and enduring: to prevent fires and to respond to those that do occur and put them out. Perhaps more than any other municipal service, the fire service is linked by a sense of fraternity and tradition, the keystones of which are reliability, dedication, esprit, heroism, and self-sacrifice [14:4].

"No major organization is more strongly tied to tradition and resistant to change than the fire service" (39:51).

> They are especially ill-eqipped to undertake efforts that involve more than minimal technological uncertainty and risk. The rewards for success within the organization are too small, and the price of failure disproportionately high [14:6].

Despite the penalties for organizational failure, the growing money crunch in local governments will force the fire chiefs to prioritize budget requirements and determine where limited resources will be allocated, to people or hardware (14:6, 31:50). The decision seems obvious.

> Salaries and benefits constitute over 98% of the fire department budget, and it is here the cost battle must be decided. Any significant reduction in costs must therefore involve a cut in numbers of people [39:52].

Arthur J. Swersey and Edward Ignall conducted a review of the research performed in the fire service area. On the specific topic of effectiveness, they found that very little

is known about how fire losses are affected by fire protection strategies (prevention, inspection, adherence to codes, early detection, sprinklers, fire department operations) and environmental factors (building construction and occupancy). They also asserted that, with the increasing costs of fire protection, the need to measure effectiveness becomes more important (35:73).

The research in fire service develops many different definitions of the basic concepts of efficiency, effectiveness, and productivity and of their relationship to each other in fire protection.

> It is difficult to measure effectiveness but if one assumes that codes are designed to prevent or limit fires and to provide life safety, and the code is being enforced to the extent that available resources allow, a degree of effectiveness must be assumed [30:30].
>
> One measure of effectiveness is how well inspectors achieve compliance. This includes not just first-time violations that are noted and corrected, but violations that stay corrected [30:27].
>
> Fire protection is optimized when the costs of fire protection plus the losses due to fires are minimized [40:13].
>
> The best indication of cost effectiveness is the combined cost/loss index [38:29].
>
> The actual effectiveness of fire departments is to a large extent a function of their capital intensity, quality of capital equipment it operates, quality of labor, and the relation between them expressed as a ratio of men to machines [23:56].

An approach by Philip B. Coulter attempted to relate the three elements of effectiveness, efficiency, and productivity.

> Effectiveness is defined as the extent to which the fire service avoids or reduces property loss, death, and injury due to fire. Prevention effectiveness refers to the degree to which the fire service avoids or minimizes the incidences of fires. ... Productivity then, measures the cost of varying levels of effectiveness by combining effectiveness and efficiency, which are theoretically independent [22:67].

Philip S. Schaenman, in his measurement of productivity in fire protection, describes productivity as the output delivered relative to the amount of input resources used, where output includes consideration of the quality and effectiveness of the service as well as the workload (32:1).

John A. Campbell, chairman of the Fire Services and Technology Educators Section of the National Fire Protection Association, says that one of the major difficulties in determining fire services cost effectiveness is the lack of standard performance levels for fire suppression (16:19).

Paul E. Andrews and John H. Erickson, at a volunteer fire council meeting, echoed Campbell's concern. They stated that performance-based results must be reorganized by state, federal and insurance organizations and that standards must be established based on the expected level of proficiency for the requirements of the community (3:44). Campbell agrees with the necessity of determining the optimum level of service desired by the community and further states that the fire service professionals must determine the optimum way to provide this service within economic constraints (16:19).

Despite the recognized need for guidance, Daniel Z. Czamanski, in his study on the cost of preventative services, found that "pieces of analysis on fire fighting are scattered among the various taxonomic studies but do not represent attempts to build models and/or develop and test theories" (23:20). Swersey and Ignall agree with Czamanski and provide seven general conclusions about fire service research.

> 1) Research that is related to local government policy decisions is sparse;
> 2) The quality of work is low, with some notable exceptions;
> 3) Little is known about fire protection effectiveness;
> 4) Little of the work is carried through to completion and implementation;
> 5) Better data are required, but - more importantly - a clear sense of what to do with these data is needed;
> 6) Research goals are often neither well-defined nor clearly understood; and
> 7) Sound statistical procedures are usually lacking [35:72].

The research that has been conducted on fire service productivity and the results of that research are summarized and examined in Chapter IV, Methodology, of this report.

Productivity in Government

In public organizations, productivity improvement has taken on increased importance as the demand for services has increased, while supporting tax revenues have lagged behind. Due to the absence of a widely accepted definition of productivity and the limited number of adequate criteria for measuring productivity in the public sector, very few

studies have attempted a quantitative analysis of government productivity (36:1, 23:16-17). The studies that have been accomplished offer a myriad of outlooks on government productivity.

A study by Charles J. Burkell, regarding productivity in governmental agencies states:

> By definition, productivity is a measure of something provided by nature, industry, or art. The measure evaluates goods and services produced (outputs) in contrast to the amount of resources utilized (inputs). At some point in the measure, a so called level of efficiency is established, which determines whether the activity is productive, nonproductive, or even counterproductive [15:25].

He further explained that "we should consider the concept of productivity as a relationship of resources to products and services, and then try to determine the effectiveness of that relationship" (15:25).

In another report by Thomas C. Tuttle (37), a comprehensive annotated bibliography of the literature on productivity measurement and enhancement was compiled from automated and manual searches of journals and computerized data bases. Most frequently, the interpretation of productivity depends on the profession from which it is approached. Tuttle categorized the productivity bibliographies into five categories: 1) the economist's view, 2) the engineer's view, 3) the accountant's view, 4) the manager's view, and 5) the industrial/organizational

psychologist's view. He concluded by stating the official Air Force view of productivity. Each is summarized below.

The Economist's View. Productivity = Outputs/Inputs. This definition of productivity is based on production theory and typically states the ratio of outputs to inputs in real or physical terms (37:7).

The Engineer's View. Efficiency = Useful Work/Energy. The engineering approach grows out of the normal expression for the efficiency of a machine (37:8). Norman and Bahiri (37:8-9) expanded this definition by considering productivity as synonymous with efficiency. In developing their efficiency relationships, they made a distinction between useful output and actual output and also between actual input and potential input.

The Accountant's View. Accountants view productivity as business efficiency. They are concerned with monitoring financial performance within an organization using a series of financial ratios (37:9-10).

The Manager's View. In 1975, Katzell, Yankelovitch, Fein, Ornati, and Nash (37:10) surveyed two groups of managers: 1) Chief of Executive Officers and 2) Industrial Relations Officers. In the survey, randomly selected managers from both groups were asked to indicate their agreement or disagreement with a number of possible statements concerning the meaning of productivity. The results are summarized in Table 2.1.

TABLE 2.1

Manager's Definition of Productivity

Productivity definition includes:	% Agreeing
1. Quality as well as quantity	95
2. Output per manhour in one company or organization	90
3. Overall efficiency and effectiveness of the operation	88
4. Disruptions, "shrinkage", sabotage and other troubles even if they are difficult to measure	73
5. Rate of absenteeism and turnover as well as output	70
6. Customer or client satisfaction	64
7. Employee loyalty, morale, or job satisfaction	55
8. Ratio of output to input by industry or sector of the economy, but not by individual organization	22

(Reprinted from Productivity, Measurements: Classification, Critique, and Implications for the Air Force [37:11])

Tuttle's conclusions from this survey were that managers tend to consider productivity to be a broad concept and that the engineer's concept or economist's concept is too narrow for this general use (37:11).

The Industrial/Organizational Psychologist's View. The term "productivity" is often found in the literature of industrial/organizational psychology, where its meaning is usually vague (37:12).

One organizational view of productivity is given by Katz and Kahn. "Katz and Kahn in their classic description of a systems view of organizations define productivity as a 'measure of role performance.' ... These authors viewed productivity as a measure of the output of an individual in his or her work role" (37:12).

Psychologists and other organizational researchers have typically given more attention to organizational effectiveness than to productivity. While the concept of effectiveness is related to productivity, the nature of this relationship is often implicit and confused (37:12).

Campbell et al., in their review, considered both productivity and efficiency as dimensions of organizational effectiveness. Coulter expressed another view of the relationship between productivity and effectiveness. In this view, productivity is the integrating concept that links effectiveness and efficiency (37:16). A third view has been prepared by Price who says that productivity (efficiency) is separate from, but related to effectiveness. He goes on to say that the two can vary independently and this is sometimes the case in business (37:17).

Productivity in the Department of Defense and the Air Force

"Largely because of pressure on the Military Services to justify budget requests, concern about productivity has increased in the Department of Defense (DOD), particularly in the Air Force" (37:i). DOD Instruction 5010.34 (August

4, 1975) and DOD Directive 5010.31 (April 27,1979) require that each DOD component develop approaches to productivity enhancement. They also put forth three separate definitions of productivity, one in terms of both efficiency and effectiveness and two that relate productivity only to efficiency (37:21). "Thus the DOD definition is unclear" (37:21).

When the Air Force issued its Productivity Plan in November 1979 in response to the DOD requirement, it adopted the narrow, efficiency definition of productivity. Though the plan acknowledged effectiveness as achieving a goal or objective, the main focus was still on efficiency (37:21).

Air Force Civil Engineering's efforts to develop a productivity measurement system has focused on results or products. The term "productivity" in this system is output divided by input, where output is measureable performance against a standard and input is required resources (funds, manpower, supplies, vehicles, etc.) to produce the output (1:IV). When applied to Fire Protection, the problem, as evidenced in literature already reviewed, will be to define that standard against which the function is measured.

III. Air Force Fire Protection

Chapter II presented the complexity of defining productivity in the public sector, particularly in the fire service. The literature also stressed the need to develop performance standards within this function in order to operate more efficiently. The difficulty of measuring fire protection performance is amplified when the function is military. A fire department in the public sector rarely has the combined responsibility for aircraft crash rescue and firefighting and structural fire protection. When a single manpower pool must be trained and ready to respond to both these areas of responsibility, as well as maintain a readiness posture for a wartime deployment mission, the task of setting standards becomes even more challenging. To clarify this challenge, an overview of the missions and structure of Air Force fire protection is presented in this chapter.

Air Force Civil Engineering will provide fire services, including the management of fire protection and prevention programs, and the execution of fire suppression in support of the Air Force mission (1:22). The Air Force Fire Department is therefore designed to provide resources for aircraft crash rescue and firefighting, and fire protection for Air Force buildings and facilities. The structure of the Air Force Fire Protection Program is shown in Figure 3.1.

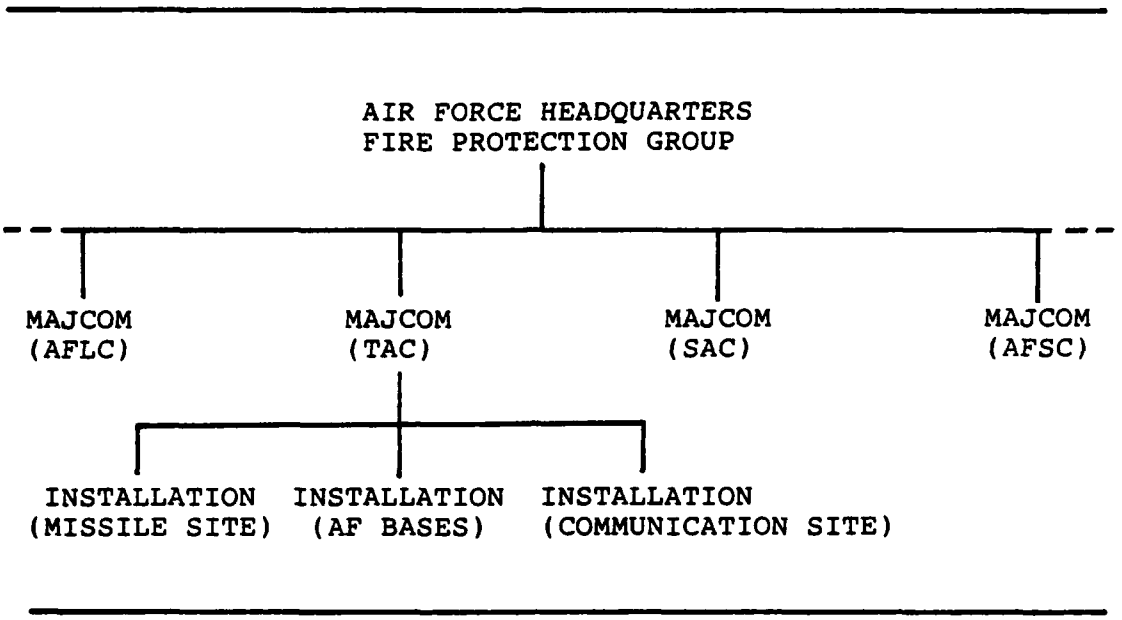


Figure 3.1. Air Force Fire Protection Program

The interest in fire protection stems from the need to protect a wide variety of operational resources in support of the basic flying mission. These resources include aircraft, buildings, equipment, supplies, information, and personnel. With this in mind, the installation program structure, shown in Figure 3.2, divides the base fire department into these categories:

1) Operations, which includes aircraft crash, fire and rescue, and structural fire and suppression;

2) Technical Services; and

3) Management.

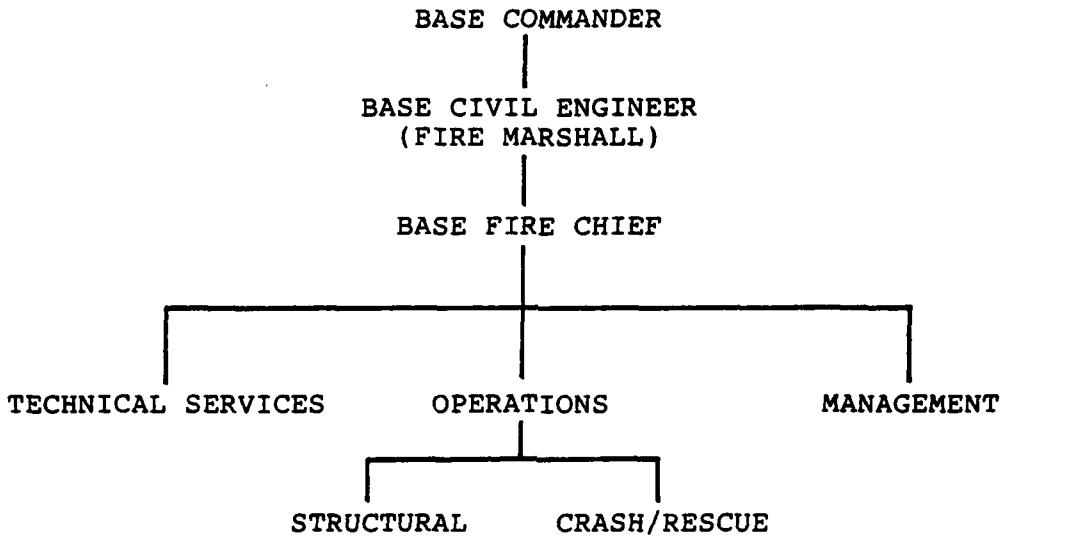


Figure 3.2. Individual Installation Fire Protection Program

Operations

The operations function of the fire department has three objectives when responding to an aircraft or structural fire incident:

1) Save lives and property;

2) Recover resources; and

3) Increase aircraft or facility salvage value (24:6).

The fire department's first responsibility is to save lives. "All initial fire fighting efforts will be expended to provide a habitable environment and an exit for entrapped persons" (24:6). Several factors influence these objectives and must be considered when trying to determine productivity

measures in the operations function. Three of these factors include:

1) assessibility to the mishap;

2) time of arrival; and

3) the amount of fire department resources that can be used.

These factors are heavily influenced by the number and location of fire stations on an airbase. "One Air Force objective is to consolidate fire departments into single adequate combination crash and structural stations" (24:7). The vehicles assigned to each station are determined by its location (structural or crash mission area). In the case of crash mission, the number and type of vehicles is based on the type of assigned mission aircraft. Structural vehicle authorizations depend on a combination of fire flow requirement (amount of water to extinguish a fire) and time-distance criteria for outlying locations (24:31).

Fire fighting personnel are authorized based on assigned vehicles. The combination of the crash and structural requirements is carried into firefighter manning by the cross-staffing concept. "Full cross-staffing means that firefighters assigned to operate one major piece of equipment are used to operate another piece of equipment intended to be used to meet another mission need" (24:6). In peacetime, however, both the crash and structural equipment are staffed to a certain extent.

Technical Services

Each Air Force installation is required by regulation to establish a fire prevention program. Fire education to the base population is stressed to enhance the total fire prevention effort. The objectives of fire prevention are twofold:

> First, eliminate the cause of fire, and second, reduce the loss of life, injuries, and property damage, if fire occurs. Achievement of these objectives requires command support at all levels and participation in the program by all base personnel. It also requires identification of deficiencies and hazards, and priority projects for their correction [24:35].

To accomplish these goals and to achieve effective fire prevention, a well-planned program managed by the fire chief is required (24:8). In this program, the installation commander enforces the requirements of the program, base personnel execute policies and procedures, and technical services personnel (from the fire department) perform fire prevention education and quality control and monitor the effectiveness of the program (24:8).

For the fire prevention program to be meaningful and effective, three basic principles must be recognized and used to develop the overall philosophy of the installation fire prevention program:

> a. Provide fire prevention education for the base population.
> b. Make sure that the proper fire protection requirements are included in activities and projects.
> c. Enforce fire prevention requirements. If specific Air Force guidance does not exist, use NFPA publications [24:35].

Management

"The main fire protection management objective is to eliminate the causes of fire and reduce loss of life, injuries and property damage if fire occurs" (24:10).

> The installation commander will provide and maintain an effective fire protection program that interfaces with the overall mishap prevention program. The Base Civil Engineer who is designated the Base Fire Marshal, administers the fire protection program [24:10].

The fire protection organization is managed by the Fire Chief who reports directly to the Base Civil Engineer.

The duties of the Base Fire Chief include 1) insuring that vehicles, equipment and personnel are always ready to operate; 2) efficiently using available resources; and 3) insuring that base plans, regulations, and operating instructions adequately address contingency fire operations (24:11). He is assisted in these duties by the Deputy Fire Chief, the Assistant Chief for Operations, the Assistant Chief for Technical Services, the Assistant Chief for Training and a Station Chief for each fire station.

The Contingency/Readiness Role

The base fire department is an essential element in developing and maintaining the readiness posture of the "total fire protection force (active duty and reserve forces firefighters)" (24:34). The fire chief, who plays a distinct and tangible role, both in peace and wartime, directly affects the efficiency of a contingency operation.

He is responsible for managing and training the firefighting Prime Base Engineer Emergency Force (BEEF) teams assigned to his base in accordance with AFR 93-3 (25), Air Force Civil Engineering Prime Base Engineer Emergency Force (BEEF) Program.

"A key concept that must be recognized both preparing for, and in conducting firefighting operations is that fire risks will increase" (24:34). Therefore, the demands on the firefighting teams that deploy, as well as the firefighters who remain at the home station to continue providing fire protection will also increase.

The two specialized firefighting teams established for Prime BEEF are the Crash Rescue/Fire Suppression Operations Team, which provides fire protection and crash rescue for contingency situations; and the Crash Rescue/Fire Suppression Control Team, which provides crash rescue and fire suppression command and control (25:2-5). When the control team is combined with two or more operations teams, the aggregate forms a base fire department capable of supporting a wartime mission (25:5).

Fire Protection Training

Fire protection training is a vital element of the fire protection program, as well as contingency operations. The training program ensures that firefighters are capable of performing effectively. "Firefighter proficiency and

effectiveness are obtained through quality instructions, proper scheduling, demonstrated performance, and evaluations to determine training needs" (24:8).

Conclusion

Air Force fire protection is a complex, challenging function that involves several sub-activities for every major one that is addressed. Any performance measurement system will have to incorporate consideration for these as well since they are an integral part of fire protection activity.

IV. Methodology

The main objectives of this study are 1) to collect historical data on the measures of Air Force Fire Department inputs and outputs that are thought to be likely ingredients of or influences on Civil Engineering Fire Department productivity; 2) to analyze this data using the Constrained Facet Analysis model to determine whether or how each data item relates to productivity; and 3) to theorize how Constrained Facet Analysis could be integrated into an automated management system to assist the Fire Chief in evaluating both efficiency and effectiveness of his fire department. Prior to the analysis of data, two search questions must be addressed:

1) Can a comprehensive set of inputs and outputs be specified to form a complete representation of Air Force Fire Department performances?

2) Of the mathematical models reviewed (regression, ratio analysis, Data Envelopment Analysis, and Constrained Facet Analysis) does the Constrained Facet Analysis model provide the best method of analyzing the data?

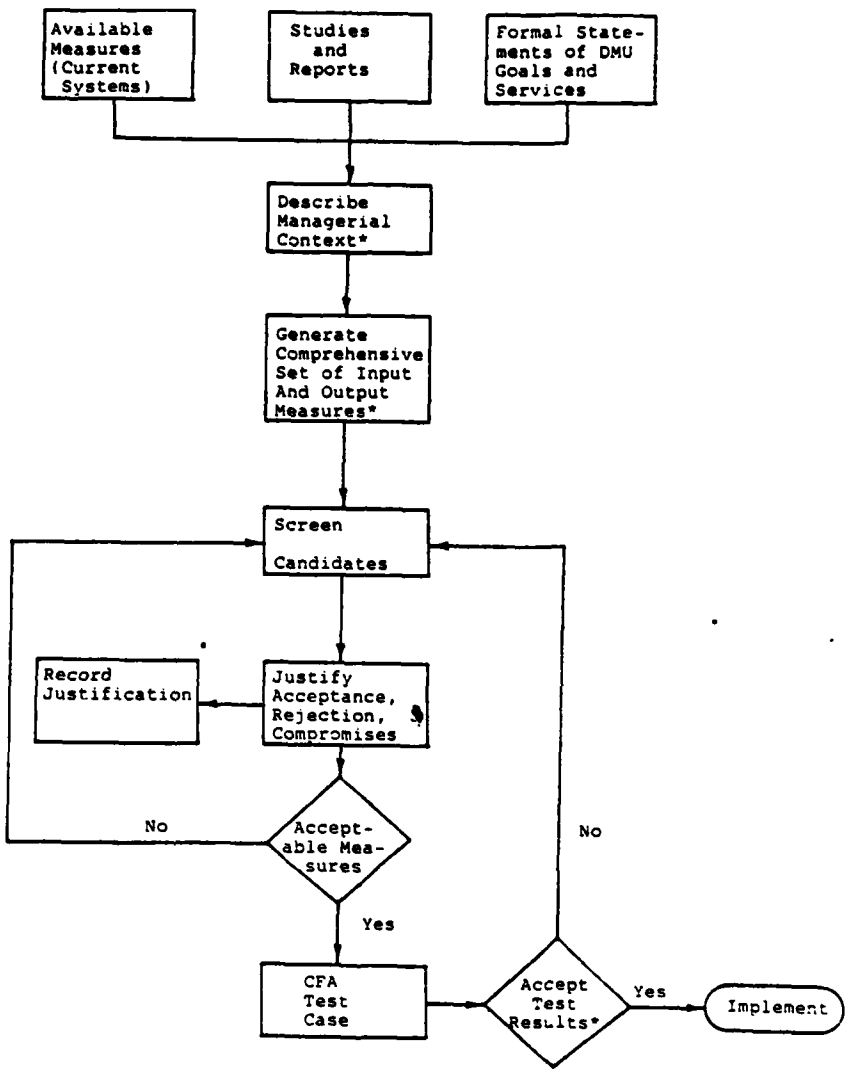
Selection of Input/Output Candidates

Selection of inputs and outputs for this research will proceed according to the guidance provided by Bessent, Bessent, and Clark in their paper, "Specificaton of Inputs

and Outputs in Data Envelopment Analysis (DEA)" (9). An outline of this procedure is provided in Figure 4.1.

Current Information Available. Reporting for Air Force Fire Departments is currently extremely limited. AFR 92-1, "Civil Engineering - Fire Protection: Fire Protection Program," requires each base to submit quarterly AF Form 1528, Fire Protection Activity Report (Figure 4.2), to its Major Command (MAJCOM). The MAJCOM's are required to consolidate these reports and submit an annual MAJCOM report to AFESC. Additionally, AF Form 278, Fire Incident Report, is required for all fires with a monetary loss to property or fires that cause loss of life or disabling injury (24:13,15). It should be noted that these reports cover only what the Department did and not how or at what cost it was done. The only other records kept by the Fire Department are the Civil Engineering records for financial management and labor reporting.

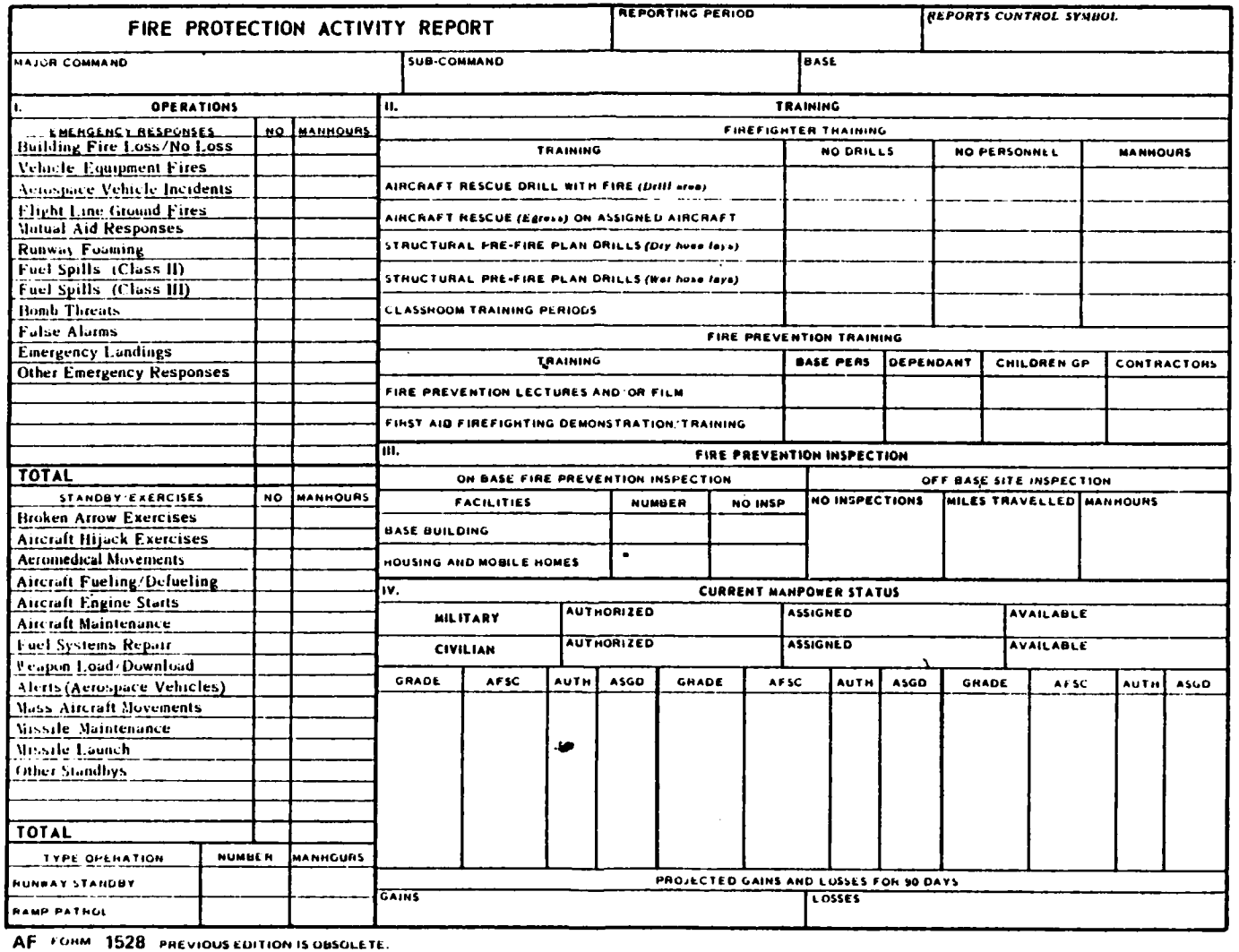
Development of Input/Output Candidates. The participants in the Fire Department functional review workshop (Appendix A) identified an exhaustive list of Fire Department tasks which are listed in Appendix B. In order to facilitate output selection, this list was further partitioned into general task categories for each of the following sub-functions: Technical Services, Operations, and Management. The selection of input/output candidates for this study was accomplished using the list of



* These Activities accomplished by CFA specialists in concert with the managers and analysts responsible for monitoring and controlling DMU's.

Reprinted from Specification of Inputs and Outputs in Data Envelopment Analysis (DEA) (9)

Figure 4.1 Specification of Inputs and Outputs



FIRE PROTECTION ACTIVITY REPORT

REPORTING PERIOD | *(REPORTS CONTROL SYMBOL)*

MAJOR COMMAND | SUB-COMMAND | BASE

I. OPERATIONS

EMERGENCY RESPONSES	NO	MANHOURS
Building Fire Loss/No Loss		
Vehicle Equipment Fires		
Aerospace Vehicle Incidents		
Flight Line Ground Fires		
Mutual Aid Responses		
Runway Foaming		
Fuel Spills (Class II)		
Fuel Spills (Class III)		
Bomb Threats		
False Alarms		
Emergency Landings		
Other Emergency Responses		
TOTAL		

STANDBY EXERCISES	NO	MANHOURS
Broken Arrow Exercises		
Aircraft Hijack Exercises		
Aeromedical Movements		
Aircraft Fueling/Defueling		
Aircraft Engine Starts		
Aircraft Maintenance		
Fuel Systems Repair		
Weapon Load/Download		
Alerts (Aerospace Vehicles)		
Mass Aircraft Movements		
Missile Maintenance		
Missile Launch		
Other Standbys		
TOTAL		

TYPE OPERATION	NUMBER	MANHOURS
RUNWAY STANDBY		
RAMP PATROL		

II. TRAINING

FIREFIGHTER TRAINING

TRAINING	NO DRILLS	NO PERSONNEL	MANHOURS
AIRCRAFT RESCUE DRILL WITH FIRE *(Drill area)*			
AIRCRAFT RESCUE *(Egress)* ON ASSIGNED AIRCRAFT			
STRUCTURAL PRE-FIRE PLAN DRILLS *(Dry hose lays)*			
STRUCTURAL PRE-FIRE PLAN DRILLS *(Wet hose lays)*			
CLASSROOM TRAINING PERIODS			

FIRE PREVENTION TRAINING

TRAINING	BASE PERS	DEPENDANT	CHILDREN GP	CONTRACTORS
FIRE PREVENTION LECTURES AND/OR FILM				
FIRST AID FIREFIGHTING DEMONSTRATION/TRAINING				

III. FIRE PREVENTION INSPECTION

ON BASE FIRE PREVENTION INSPECTION			OFF BASE SITE INSPECTION		
FACILITIES	NUMBER	NO INSP	NO INSPECTIONS	MILES TRAVELLED	MANHOURS
BASE BUILDING					
HOUSING AND MOBILE HOMES					

IV. CURRENT MANPOWER STATUS

MILITARY	AUTHORIZED	ASSIGNED	AVAILABLE
CIVILIAN	AUTHORIZED	ASSIGNED	AVAILABLE

GRADE	AFSC	AUTH	ASGD	GRADE	AFSC	AUTH	ASGD	GRADE	AFSC	AUTH	ASGD

PROJECTED GAINS AND LOSSES FOR 90 DAYS

GAINS | LOSSES

AF FORM 1528 PREVIOUS EDITION IS OBSOLETE.

Figure 4.2 Fire Protection Activity Report (AF Form 1528)

Figure 4.2 Continued

V. FIREFIGHTING AND SUPPORT VEHICLE STATUS

TYPE VEHICLE AND REGISTRATION NUMBER	MILES DRIVEN THIS PERIOD	HOURS OUT-OF-COMMISSION (F.D. Use)	FIRE STATION ASSIGNED	REASON FOR EXCESSIVE OUT-OF-COMMISSION TIME (36 hours per month)

REMARKS (Including vehicles received and turned in)

APPROVED BY (Typed Name, Grade, Title and Telephone #)	SIGNATURE

categories, taking into consideration the current availability of data.

At this stage in the identification process, the candidates must meet the criteria below (9:3).

1. Outputs represent important Fire Department goals.

2. All measures are appropriate and common to all Fire Departments and exist in nonzero amounts.

3. Inputs represent all the physical quantities used by the units towards attainment of outputs.

4. There is a conceptual basis for believing that changes in the ouputs should be caused by changes in the inputs.

5. The magnitudes of physical input/output quantities are represented.

6. The quality of inputs and outputs is represented.

Additionally, the "isotonic" property (which means as an input increases/decreases the output measure should also increase/decrease and vice-versa) has been insured by using the reciprocal value where appropriate.

Output candidates for this analysis will be of two types: results and process measures. Results measures are stated in measurable terms and are related to an organizational objective. Included in this category are surrogate or proxy measures. These quantifiable measures represent the closest feasible representation of an achievement that is not itself directly measurable. A

process measure relates to an organizational activity rather than to the objective. An input used as an output when no other measure is available is included in this category. (4:232-233, 249)

The comprehensive set of input and output candidates selected for this analysis, presented with category justification and source information, are in Appendix C. Chief Master Sergeant Bryce Mason, AFESC Fire Protection Division, reviewed the candidate selections and validated the appropriateness of the measurements (28). He also assured that these factors represent a complete description of the Fire Department activities. With the completion of this review, the assertion can be made that the first research question, to collect historical data on the measures of Air Force Fire Department inputs and outputs that are thought to be likely ingredients of or influences on Civil Engineering Fir Department productivity, has been positively addressed.

Alternative Methods of Measuring Air Force Fire Department Efficiency

The literature review illustrated that fire service productivity is multi-factored. At this time, a method has not been developed which combines all these factors into one true indicator of fire service productivity. In an attempt to fill this void, Constrained Facet Analysis (20) will be

used in this research to measure the relative efficiency of Air Force Fire Departments.

Constrained Facet Analysis (CFA) is a new approach which provides a range of efficiency (an upper and lower bound) and takes into account the relationship between multiple inputs and multiple outputs when measuring the relative efficiency of a decision making unit. This method, which has been developed by Bessent, Bessent, Clark, and Elam, (11) is an extension of the Charnes, Cooper, and Rhodes (19) efficiency model called Data Envelopment Analysis (DEA), which establishes the highest possible efficiency rating for a decision making unit based on the evaluation of empirical data.

A detailed discussion of both Data Envelopment Analysis and Constrained Facet Analysis will follow, but first, a review of some of the research and methods employed thus far to measure fire service efficiency and their shortfalls will be presented. Although substantial research has not been accomplished in the field of fire service productivity, it is interesting to observe that the research that has been done seems to be aimed in multiple directions. This, in part, is due to the disagreement by fire service experts on how to measure fire service productivity.

Arthur J. Swersey and Edward Ignall (35) evaluated much of the fire service research done through 1979. They gave the topic of measuring effectiveness and productivity a

high priority for future research, affirming that little investigation has been done in this area (35:67). Their overall assessment of the research performed at the time identified the following deficiencies: 1) that quality data was lacking and, more importantly, a clear sense of what to do with this data is needed (35:72) (32:93); and 2) sound statistical procedures are usually lacking in the research studies (35:72).

Mr. Waters reiterated the first deficiency after commenting on a study of 50 city fire departments conducted by a consortium of the National Science Foundation, the National Fire Protection Association, the International City Management Association, and the Research Triangle Institute (39:52). One of the significant features in this benchmark study is the use of nationwide efficiency and productivity measures to judge how a Fire Department compares with others. Waters points out that there is a need for empirical measures using readily available data (39:52).

Of the mathematical techniques used in fire service research, the ones most commonly found are pairwise comparison, ratio analysis, and linear regression. In the pairwise comparison measurement method developed by Schaenman and Swartz, Schaenman and Swartz noted that interactions between resources (inputs) and the Fire Department's services (outputs) were not taken into account. This fact caused somewhat misleading conclusions about a

fire department's efficiency because each pairwise comparison reflected only a few dimensions of the fire protection services rendered, when several measures and factors were needed to describe fire prevention and fire suppression efficiency and productivity (32:14).

Ratio Analysis. Charles P. Shannon, Director of Management and Human Services at the Denver Regional Council of Governments, conducted a research study identifying indicators, in the form of ratios, associated with the performance of fire service operations. He noted that first the ratio data had to be collected and then the data had to pass the tests of relevance, timeliness, accuracy, availability, and comparability. He further pointed out that a comprehensive performance measurement system that relies on ratios and comparative data will undoubtedly fail to meet all of these tests (33:55).

The limitation of ratios, and ratio analysis in particular, is provided by Bessent, Bessent, and Clark (6). Their paper identifies the benefits and shortcomings of ratio analysis when compared to Data Envelopment Analysis, and their major points will be presented here. Ratio analysis is a simple ex post facto method of comparing the performance of similar organizations with multiple inputs and multiple outputs. Ratio analysis examines these multiple measures in the form of ratios that are familiar to managers and that are easy to calculate because each ratio

is typically a single output measure divided by a single input measure.

The major shortfall of ratio analysis is that it does not make use of mathematical models which take into account the interactions over the full range of inputs and outputs simultaneously. As a result, ratio analysis cannot accurately compare the performance of similar organizations, particularly when an organization ranks high on some measures and low on others (6).

Bessent, Bessent, and Clark (6:15) provide a useful discussion of the following ratios by using illustrative examples, and they also discuss the problems encountered with each ratio:

1. Percentages (assigned / authorized)
2. Ouput / Input
3. Input / Output
4. Input / Input
5. Output / Output

Basically, the information obtained from these ratios is often misleading because the ratios provide only a partial measure of multiple input, multiple output relationships, resulting in erroneous conclusions about productivity.

Although percentages and other ratios are easily calculated and are familiar to managers, the use of these measures in Constrained Facet Analysis can result in a failure to explictly take into account the magnitudes of the

outputs or inputs which are found in the numerators and denominators of the ratios. Bessent, Bessent, and Clark suggest that ratios should be broken down into their physical input and output components for the Constrained Facet Analysis evaluation. The input/output measures could be put back into ratio form after the Constrained Facet Analysis so that managers could use them while interpreting Constrained Facet Analysis results.

Linear Regression. The other common mathematical tool used to measure efficiency in the fire service is linear regression. Daniel Z. Czamanski, in his book The Cost of Preventive Services (23) defined the concept of productivity in public service and then developed a model of the relationship of fire losses and fire expenditures using simple linear regression. Czamanski went on to examine the notions of "average" and marginal productivity as a relation of outputs and inputs, and production efficiency as optimal allocation of a resource (23:29). He noted the same limitations of linear regression analysis that were pointed out by Bessent, Bessent, and Clark (6:2) in their discussion comparing regression to Data Envelopment Analysis. A brief discussion of Bessent, Bessent, and Clark's findings follows.

Linear regression is a single output, multiple input way of evaluating the efficiency of an organization. Regression has both positive and negative error terms and

tries to fit an "average relationship" curve which estimates the relationships between the multiple inputs and single output. One major problem of regression analysis is that these "average" curves do not represent frontiers which by definition are based on extremal relations. Bessent, Bessent, and Clark (6:2) note average estimates are uninformative or misleading as frontier estimations when compared to Data Envelopment Analysis results. In their discussion comparing Data Envelopment Analysis to regression, they noted three shortcomings of linear regresson analysis:

1. Regression estimates often fail to identify the existence and degree of inefficiency in organizations.
2. Multiple outputs may contain interactions which are undetected by regressions performed on each output separately.
3. Regression estimates confound inefficient and efficient units. Better regression estimates are obtained using efficient units only. [6:2]

The "average relationship" curve produced by regression is not a true efficiency frontier for a given set of observations. An efficiency frontier is made up of those observations that are relatively efficient compared to other observations with similar input/output mixes. All other observations not on the efficiency frontier are relatively inefficient; and in fact, an inefficient observation can only be on one side of the frontier since a frontier represents the "best" an organization can be. The

residuals, or error terms, that make up the regression's "average" curve can take on both positive and negative values that fall both above and below the "average relationship" curve respectively. A true efficiency frontier does not have observations on either side of the curve; therefore, the size and direction of the linear regression's residuals, or error terms, result in misleading information about the organization.

One of the main reasons why regression analysis will not be used as an efficiency model in this study is that it cannot take into account the relationships between multiple outputs and multiple inputs. Analysis of fire departments requires the capability to analyze relationships between multiple inputs and multiple outputs, including the effects of the interactions between outputs competing for the same resources (inputs).

The third shortcoming of linear regression noted by Bessent, Bessent, and Clark (6:6) occurs when organizations are operating under different technologies. Although two organizations have the same amount of inputs, the organization with the highest level of technical efficiency would have a higher level of output. The difference in the expected output levels of the two organizations would be accounted for in the regression's residual term. Since the regression estimates are influenced by both efficient and inefficient observations simultaneously, the resulting

average curve and regression equation could misrepresent both organizations. Bessent, Bessent, and Clark provide a more detailed discussion of these shortcomings in their working paper titled, "Notes Comparing DEA to Statistical-Econometrics and Ratio Analysis" (6).

Data Envelopment Analysis. A short discussion on Data Envelopment Analysis (DEA) is provided as the basis for the Constrained Facet Analysis (CFA) model that will be used in this thesis. It should be noted that the first iteration of the CFA linear programming model is in fact DEA, which provides an upper bound of efficiency for a unit; and the second iteration of CFA provides a lower bound of efficiency for those units considered to be outliers, units that are not fully explained by other units with similar input/output mixes.

Data Envelopment Analysis is a fractional programming model developed by Charnes, Cooper, and Rhodes in 1978 (18,19) to measure the relative efficiencies of like units. Literature on Data Envelopment is limited, but Bessent, Bessent, and Clark provide a comprehensive summary on the theory and its development, the mathematical model used in DEA and the model's requirements, and a brief review of DEA applications to date (7). The following summarizes their views.

The major advantage of Data Envelopment Analysis (DEA) over regression and ratio analysis and the reason why this

model is preferred is that DEA provides a way to take multiple outputs and multiple inputs into account simultaneously, including differences in input/output mixes and tradeoffs among factors. By doing so, it provides information on the interaction of the input and output measures (7).

Although DEA appears to be an excellent alternative for analysis of nonprofit organizations, it does have some limitations. In DEA, organizations that are not fully explained (or not fully enveloped) are sometimes given efficiency ratings which seriously overestimate the actual efficiency (7). This occurs because weights or multiplier values are assigned by the model to each output and input in order to maximize the efficiency rating of the decision making unit being evaluated. These weights are not known prior to the evaluation but, rather, they are derived from the empirical data used in the ex post facto evaluation (34:2.58). It became apparent that in many situations it would be unreasonable for an outlier unit to be given so high an efficiency rating, given the available inputs and outputs. Constrained Facet Analysis addresses this problem and provides more information on this outlier unit.

Constrained Facet Analysis

A practical way to explain Constrained Facet Analysis (CFA) and the outlier units is by geometric representation. The CFA model first identifies an efficiency frontier made

up of organizations "which achieve the highest level of output for their given levels of input" (11:3). Figure 4.3 illustrates the frontier concept, which is explained below. The observed organizations A through D form a piecewise linear frontier made up of individual frontier segments or facets $\overline{AB}$, $\overline{BC}$ and $\overline{CD}$. When all the frontier facets are connected together, as shown in Figure 4.3, a CFA efficiency frontier, ZZ', is formed. There are two types of frontier facets that must be defined. The first is the "proper" facet. A proper facet has two actual units forming the segment or facet, such as segment $\overline{BC}$, where the segment has a negative slope. The second type of CFA facet is called an "artificial" facet. The facets $\overline{DM}_1$ and $\overline{DM}_2$ are artificial facets because each is formed by only one actual unit, D or A, and a point which is not an actual observed input combination, M_1 or M_2. Furthermore, the slopes of these artificial facets are zero and undefined respectively.

The CFA efficiency rating can be easily obtained geometrically for units that are on the frontier and that are "fully enveloped." A unit is considered fully enveloped if a ray from the origin to the observed unit crosses a proper frontier facet. In Figure 4.3 units E, F, and G are fully enveloped by facets $\overline{AB}$, $\overline{BC}$, and $\overline{CD}$ respectively.

The only observed unit not fully enveloped in Figure 4.3 is unit H. A unit is considered an outlier or not fully enveloped if a ray from the origin to the actual unit, H,

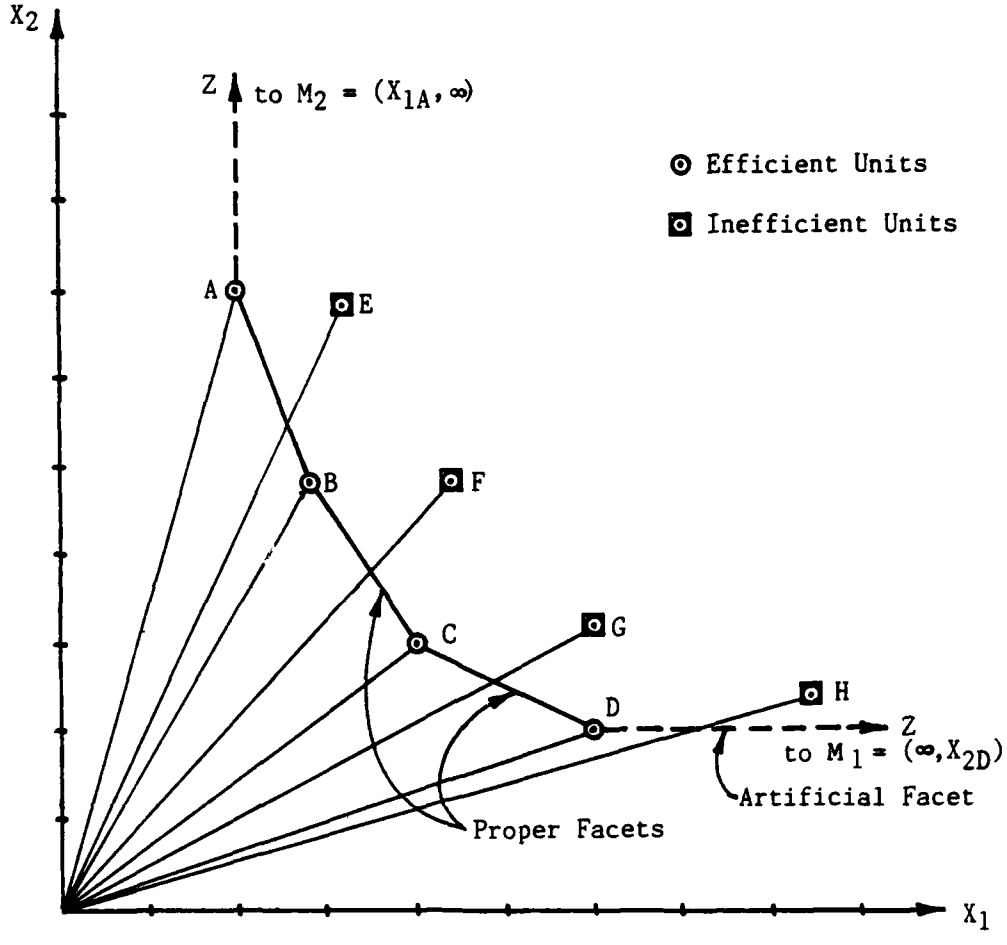


Figure 4.3 CFA Frontier made of Efficient Units

does not cross a proper facet but, rather, crosses an artificial facet like $\overline{DM}_1$.

Now that the general concepts of CFA have been explained, a geometric interpretation of a single output/two input situation for four fictitious fire departments will follow (21). Suppose the fire departments A, B, C, and D shown in Table 4.1 each produced the same product, Y, using the same two resources, X_1 and X_2, during some specified time period. The actual amounts of resources X_1 and X_2 used to produce Y and the amount of product Y produced by a fire department are divided by the value of Y to scale the unit observations to facilitate comparison, and these scaled values are recorded in Table 4.2. The results of this scaling are then plotted on a two-dimensional graph and a piecewise linear frontier is established. The frontier is created by connecting the points nearest the origin with line segments as shown in Figure 4.4. In this example there is one proper facet $\overline{BC}$, and two artificial facets $\overline{CM}_1$ and $\overline{BM}_2$.

TABLE 4.1

CFA Data Set for Four Fire Departments

Fire Department	Output Y	Input X_1	Input X_2
A	3	15	21
B	5	20	20
C	1	5	2
D	2	12	8

TABLE 4.2

CFA Observations with Common Output Y/Y

Fire Department	Output Y/Y	Input X_1/Y	Input X_2/Y
A	1	5	7
B	1	4	4
C	1	5	2
D	1	6	4

The concepts of fully enveloped and not fully enveloped for this example are illustrated in Figure 4.5. Since ray $\overline{OD}$ crosses the frontier segment $\overline{BC}$, unit D is considered fully enveloped by efficient units B and C. Unit A, on the other hand, is not fully enveloped and is considered an outlier because ray $\overline{OA}$ crosses the artificial facet $\overline{BM}_2$ rather than a proper facet.

Once the observations are plotted and the piecewise linear efficiency frontier is formed, the CFA efficiency rating for each unit can be determined. A single efficiency measure can be obtained geometrically for units that are on the frontier and that are fully enveloped. For units that are considered outliers and are not fully enveloped a single efficiency rating cannot be obtained. However, a range of efficiencies with an upper bound and a lower bound can be found. This range gives managers some idea of their inefficiencies.

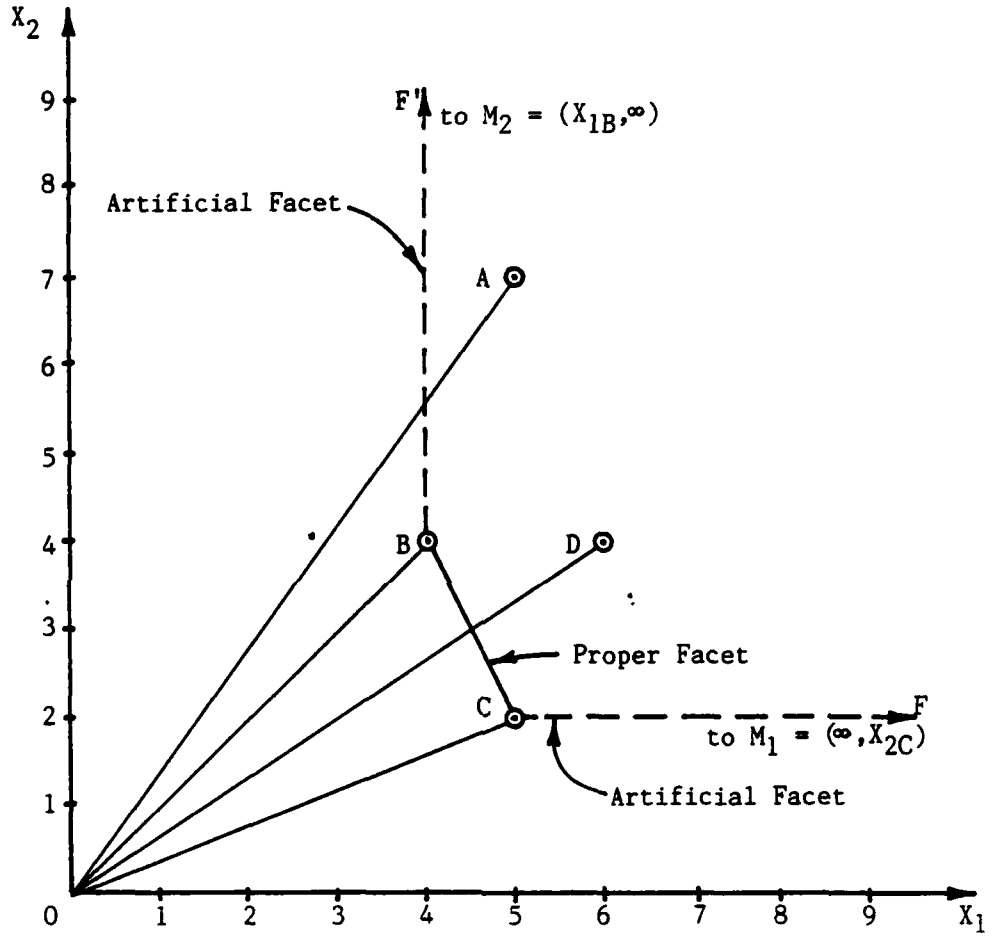
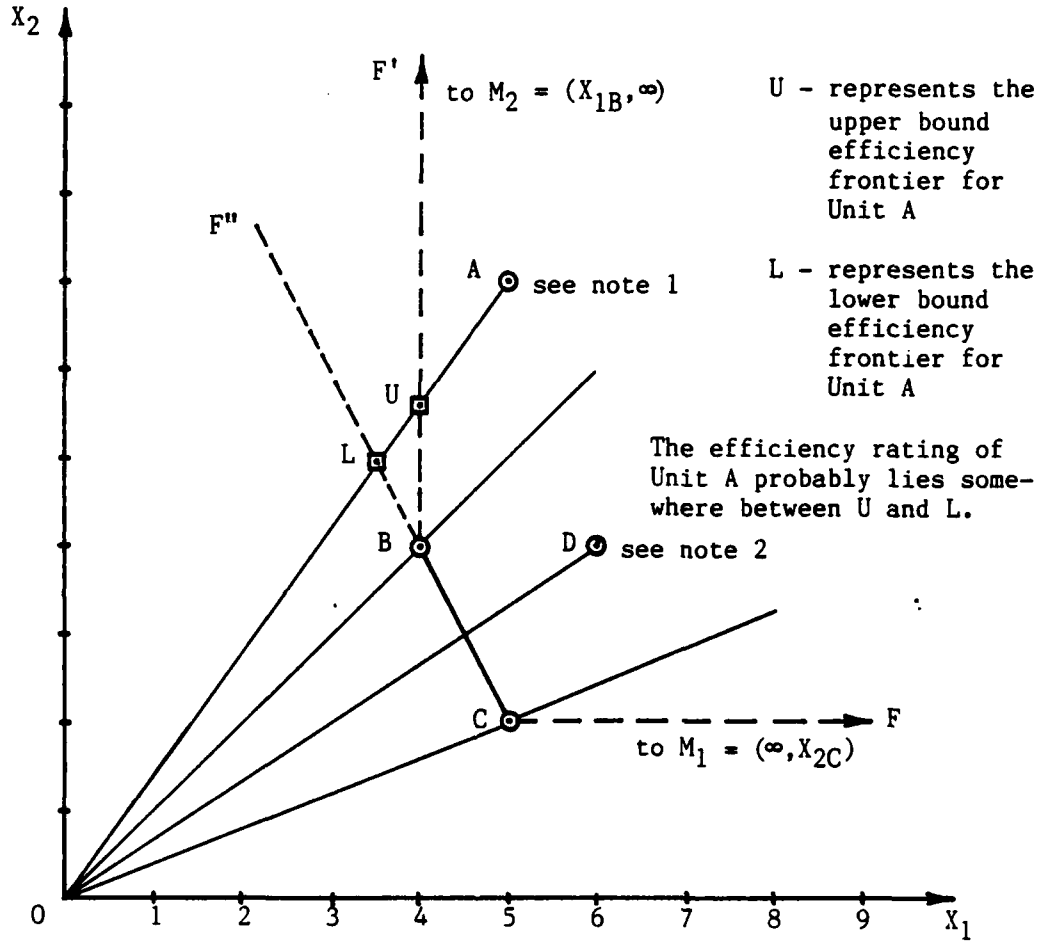


Figure 4.4 CFA Observations Plotted and the Piecewise Linear Frontier (FF') is Formed



Note 1: Unit A is an "outlier" or "not fully enveloped" unit. Unit A can only be compared with efficient Unit B on the FF" frontier but can be compared to units B and C on the FF" frontier.

Note 2: Unit D is "fully enveloped". Unit D can be compared with efficient units B and C on the frontier facet.

Figure 4.5 CFA Concepts of Fully Enveloped and Not Fully Enveloped

Specifically, the efficiency ratings for units A through D can be determined geometrically by following these four steps:

1. Draw rays from the origin to each point A, B, C, and D;

2. Measure the distance along each ray from the origin to the frontier it crosses;

3. Measure the distance from the origin to the observed point; and

4. Calculate the efficiency by dividing the distance to the frontier by the distance to the point.

Figure 4.6 and Table 4.3 illustrate the four-step efficiency rating method, and the following characteristics can be noted from the efficiency rating results. Since units B and C are on the frontier, their efficiency ratings are equal to 1.0, and they are relatively efficient when compared to units A and D for this example. Units A and D are not efficient relative to frontier facet $\overline{BC}$; therefore, their efficiency ratings are less than 1.0.

Since observation D is fully enveloped, a single efficiency rating can be obtained by taking 13.8 centimeters, the distance from the origin to the proper facet, and dividing by 18.4 centimeters, the distance from the origin to the observed point D, for an efficiency rating (h_D^{U*}) equal to 0.75. Unit D was compared to efficient units B and C, which have similar input/output mixes as unit D.

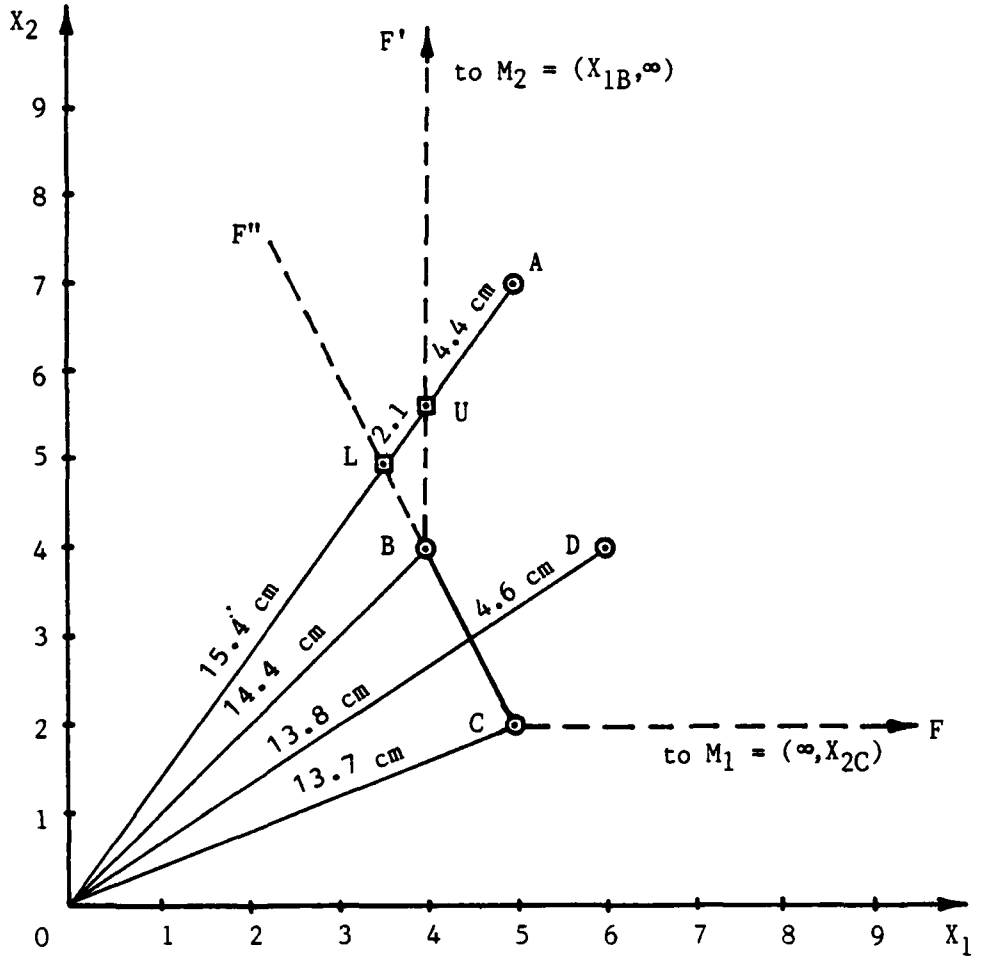


Figure 4.6 Graphical Determination of CFA Efficiencies

TABLE 4.3

CFA Efficiency Ratings for Four Fire Departments

Fire Department	Distance to Frontier (cm)		Distance to Observed Point (cm)	Efficiency	
				Upper Bound h_j^{U*}	Lower Bound h_j^{L*}
	FF'	FF"			
A	17.5	15.4	21.9	.800	.703
B	14.4	-	14.4	1.000	-
C	13.7	-	13.7	1.000	-
D	13.8	-	18.4	.750	-

The upper bound efficiency measure for unit A is achieved by comparing unit A to efficient unit B only. In Figure 4.6, the upper bound efficiency rating for A is found by dividing the distance from the origin to the point U by the distance from the origin to the observed unit A. As shown in Table 4.3 the upper bound measure (h_A^{U*}) is equal to 0.800.

The lower bound efficiency measure is found in a similar manner. The difference is that the lower bound efficiency for unit A is measured relative to units B and C instead of unit B alone. From Figure 4.6, the lower bound rating (h_A^{L*}) is obtained by dividing the distance from the origin to the point L by the distance from the origin to the observed unit A. Results of units A, B, C, and D efficiency ratings are shown in Table 4.3.

A large range between the upper and lower bounds of efficiency implies that we cannot fully explain the inefficiency for that particular unit, and that a closer inspection of this outlier is required before conclusions can be drawn (11:15). On the other hand, if "the difference between the upper and lower bound measures is relatively small" (11:15) for a particular unit, then the mix of inputs and outputs of that unit is similar to the units in the nearby frontier facet.

Given that a manager can obtain an efficiency rating for the organization's ability in using inputs to produce outputs, what can be done to improve the efficiency of the organization? Two frontier concepts, marginal rates of substitution and marginal rates of productivity, can be obtained from CFA. These rates provide valuable information so managers can make tradeoffs between resources and products or services to improve the unit's efficiency rating. These marginal rates can be computed by using input and output "multiplier" values which will be defined and explained below.

The input/output multipliers of the CFA model are used to adjust the observed values to simulate how an inefficient organization can reallocate resources and alter current services to become a more efficient organization. The multipliers are obtained by extending a frontier facet like $\overline{BC}$ in Figure 4.7 to each axis, X_1 and X_2. One set of

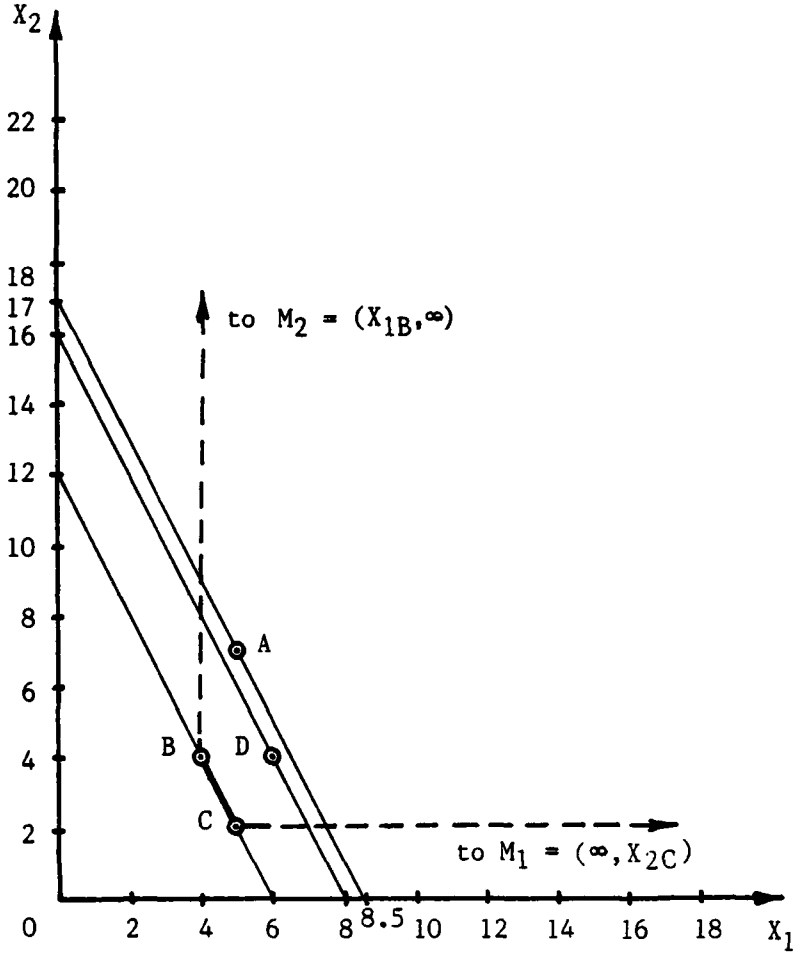


Figure 4.7 CFA Multipliers

multipliers consisting of two multiplier values, one for each axis, can be determined geometrically for each efficient unit and fully enveloped inefficient unit. The first input multiplier for unit B is found by extending the $\overline{BC}$ facet until it crosses the X_1 axis. The point (6,0) is the point of intersection. The reciprocal of the X_1 value is the first input multiplier v_1 and it equals 1/6. The second multiplier v_2 for unit B is obtained in a similar manner. The intersection of the extended BC facet and the X_2 axis is the point (0,12). Therefore, the input multiplier v_2 equals 1/12. Similarly, for inefficient unit D, which is fully enveloped by units B and C, the multipliers are obtained by extending a line through point D, which is parallel to the proper facet $\overline{BC}$ in this case.

Unlike the efficient units and the inefficient units that are fully enveloped, outlier units like unit A that are not fully enveloped have two sets of multipliers. The first set is found by drawing a line through A that is parallel to the X_1 axis and the artificial frontier facet $\overline{BM}_2$. This line intercepts the X_1 axis at (5,0), but does not intercept the X_2 axis. Therefore, the v_1 input multiplier for unit A equals 1.5 and the v_2 input multiplier equals zero ($1/\infty$). The second set of multiplier values is obtained by drawing a line through A parallel to the closest proper facet $\overline{BC}$. The multipliers are obtained in a similar fashion. Figure 4.7 shows all the intercept values for each unit, and Table 4.4

summarizes the information from Figure 4.7 and the input multipliers obtained.

Once the multipliers are determined, they can be manipulated in conjunction with the efficiency (h_j^*) to obtain both the marginal rates of substitution and marginal rates of productivity by using the following formulas:

$$\text{Marginal Rate of Substitution of Input } X_1 \text{ for Input } X_2 = -\frac{\nu_2}{\nu_1}$$

$$\text{Marginal Rate of Productivity of Input } X_1 \text{ in Producing Y} = \frac{\nu_1}{h_j^*} \qquad j = A,B,C,D$$

$$\text{Marginal Rate of Productivity of Input } X_2 \text{ in Producing Y} = \frac{\nu_2}{h_j^*} \qquad j = A,B,C,D$$

"These rates are useful and informative because they are derived from the nearest set of empirical observations" (11:16). These rates which might be used in planning productivity improvements have been calculated for the data from Table 4.4 using the above formulas, and the results are shown in Table 4.5.

The negative values of the rates of substitution also represent the slope of the frontier facet to which the unit is compared. For example, unit D is associated with facet $\overline{BC}$ and the slope of that facet is -2. From Table 4.5, unit

TABLE 4.4

CFA Intercepts and Multiplier Values for Four Fire Departments

Fire Department	Intercepts				Input Multipliers			
	X_1		X_2		ν_1		ν_2	
	First	Last	First	Last	First	Last	First	Last
A	5	17/2	0	17	1/5	2/17	0	1/17
B	6	-	12	-	1/6	-	1/12	-
C	6	-	12	-	1/6	-	1/12	-
D	8	-	16	-	1/8	-	1/16	-

TABLE 4.5

CFA Marginal Rates of Substitution and Marginal Rates of Productivity for Four Fire Departments

Fire Department	Rate of Substitution $\frac{\nu_1}{\nu_2}$		Rate of Productivity $\frac{\nu_1}{h_j^*}$		Rate of Productivity $\frac{\nu_2}{h_j^*}$	
	First	Last	First	Last	First	Last
A	$\frac{-1/5}{0} = \infty$	$\frac{-2/17}{1/17} = -2$	$\frac{1/5}{4/5} = 1/4$	$\frac{2/17}{12/16} = 1/6$	$\frac{0}{4/5} = 0$	$\frac{1/17}{12/16} = 4/51$
B	$\frac{-1/6}{1/12} = -2$	—	$\frac{1/6}{1} = 1/6$	—	$\frac{1/12}{1} = 1/12$	—
C	$\frac{-1/6}{1/12} = -2$	—	$\frac{1/6}{1} = 1/6$	—	$\frac{1/12}{1} = 1/12$	—
D	$\frac{-1/8}{1/16} = -2$	—	$\frac{1/8}{3/4} = 1/6$	—	$\frac{1/16}{3/4} = 1/12$	—

D's value of -2.0 indicates the marginal rate of substitution between input X_1 and input X_2. Thus, if unit D is operating efficiently, an increase of one unit of resource X_1 would require a decrease of approximately 1 x 2.0 = 2 units of resource X_2, provided the output amount remains constant (11:16). The same input relationship is true of the other inefficient unit A.

The marginal rate of productivity values are positive values which represent the amount that outputs are influenced by a change in inputs. For example, if unit D's resource X_1 is increased by one unit, a positive increase of approximately ν_1/h_j^* units of output Y would be required for the unit to remain efficient, provided of course that the X_2 amount remains the same.

As mentioned previously, managers of inefficient units would like to know which changes in resources (inputs) or products/services (outputs) would lead to an efficient rating. As noted by Clark (21) there are an infinite number of alternative input/output combinations which an inefficient unit could adopt to achieve the frontier of relative efficiency. These alternatives can be obtained from the optimal solutions of Constrained Facet Analysis. For more details in this area see Appendix D.

CFA can be explained mathematically as well as geometrically. For those readers who are interested in the mathematical interpretation of CFA, the same single output

two input example illustrated geometrically above is also presented mathematically in Appendix D. The CFA primal and dual linear programming models that are used in mathematical illustration are found in Appendix E.

Although CFA was explained here for a simple single output two input situation in two dimensions, CFA can also be used for multiple input and multiple output situations where the geometric interpretation would be multi-dimensional and impossible to represent graphically. However, the mathematical program can be solved by computer and CFA results can be obtained for use by managers even in multiple input, multiple output situations. The Constrained Facet Analysis code is currently on the TAURUS CDC Cyber 170/750 mainframe computer at the University of Texas.

Of the mathematical models reviewed thus far, only Constrained Facet Analysis can distinguish between relatively efficient units and inefficient units for non-profit organizations with multiple inputs and multiple outputs. CFA is also the only mathematical model reviewed that considers all input/output measures simultaneously while providing multipliers (weights) for each input and output which are derived empirically.

With the completion of this comparison of mathematical models, it has been shown that the Constrained Facet Analysis model apparently does provide the best method of analyzing the data.

V. Selection of Inputs and Outputs

At this point in the research process the method of analysis was determined to be Constrained Facet Analysis (CFA). CFA can evaluate an organization based on a set of multiple inputs and multiple outputs, and can simultaneously evaluate the set of inputs and outputs to produce an upper bound and lower bound of efficiency for each organization. The CFA model will also identify the sources of inefficiency in those organizations receiving an inefficient rating.

This chapter will review the data collection procedure, the problems encountered with the data collected, the format required by the constrained facet analysis code for the data set, and the reduction of the data to satisfy CFA requirements.

The comprehensive set of input and output candidates collected are those used by Fire Chiefs and upper level managers, and were chosen to highlight the key objectives, operating characteristics and input factors of Air Force Fire Departments. The comprehensive set of input/output candidates in Appendix C is complete in the sense that all of the relevant Fire Department goals for each branch (Operations, Technical Services, and Management) can be evaluated using this set.

Collection of Data for Input/Output Candidates

The collection of data for this research was accomplished using the data information form shown in Figure 5.1. Accompanying the data form were attachments containing instructions for form completion. The complete data information package is contained in Appendix F. Most of the instructions were specified by referring to AF Form 1528, Fire Protection Activity Report (Figure 4.2), and AF Form 278, Fire Incident Report. Some data required more extensive instructions for using Base Engineer Automated Management System (BEAMS) retrieval or budgeting reports, and these instructions were developed with the assistance of Ms Alice Anderson (2) a Management Analyst at Wright-Patterson AFB Ohio.

When the instructions were complete, the data information package was reviewed for accuracy, completeness, and data availability by the following persons:

Major Philip M. Ray
Readiness Team Chief AFESC/DEF Tyndall AFB FL

Chief Master Sergeant Bryce E. Mason
Fire Protection Manager AFESC/DEF Tyndall AFB FL

Chief Master Sergeant Guy J. Wills, Jr.
Acting Fire Chief 3202 CES/DEF Eglin AFB FL

Master Sergeant Joe Ybarra
Fire Protection Supervisor
HQ AFSC/DEMF Andrews AFB MD

CONSTRAINED FACET ANALYSIS INPUT/OUTPUT MEASURES
FOR AF FIRE DEPARTMENTS

DEMOGRAPHIC DATA

Base Name (1) _____

State Code (2) _____ Region Code (3) _____ MAJCOM Code (4) _____

Base Civil Engineer's Name (5) _____ Autovon (6) _____

Fire Chief's Name (7) _____ Autovon (8) _____

	NUMBER	MANHOURS
Aerospace Vehicle Responses	(9) _____	(10) _____
Building Fire Responses	(11) _____	(12) _____
Housing	(13) _____	(14) _____
Other	(15) _____	(16) _____
Fuel Spill Responses	(17) _____	(18) _____
Mutual Aid Responses	(19) _____	(20) _____
Other Responses	(21) _____	(22) _____
Aircraft Standbys	(23) _____	(24) _____
Other Standbys	(25) _____	(26) _____
Aircraft Rescue Drills	(27) _____	(28) _____
Structural Drills	(29) _____	(30) _____
Classroom Training	(31) _____	(32) _____
Prime BEEF Training	(33) _____	(34) _____
Documents Reviewed	(35) _____	(36) _____
In-service Work	(37) _____	(38) _____
Contract Work	(39) _____	(40) _____

	HOUSING	OTHER	TOTAL
Building Fire Loss ($)	(41) $ _____	(42) $ _____	(43) $ _____
Loss per Reportable Fire ($)	(44) $ _____	(45) $ _____	(46) $ _____
Total # of Inspections	(47) _____	(48) _____	(49) _____

Total # of Inspectors (50) _____

Fire Related Deaths: Base Populace (51) _____ Firefighters (52) _____

Fire Related Injuries: Base Populace (53) _____ Firefighters (54) _____

Figure 5.1 Constrained Facet Analysis Data Request Form

Total # of Prevention Presentations: on-base (55) _____ off-base (56) _____

Total # of Landings and Take-offs (57) _____

Land Area (acres) (58) _____

Expenditure ($)

Civilian Pay (59) $ _____ Military Pay (60) $ _____

Supplies (61) $ _____ Equipment (62) $ _____

Contracted Services (63) $ _____

MANHOURS	TOTAL	TOTAL AVAILABLE
Total Fire Department	(64) _____	(65) _____
Operations	(66) _____	(67) _____
Technical Services	(68) _____	(69) _____
Civilian	(70) _____	(71) _____
Military	(72) _____	(73) _____
Skill Level		
57190	(74) _____	(75) _____
57170	(76) _____	(77) _____
57150	(78) _____	(79) _____
57130 - 57110	(80) _____	(81) _____
57100	(82) _____	(83) _____

Real Property Value at Risk (excluding aircraft) (84) $ _____

Housing Value at Risk (85) $ _____

Industrial Structure Value at Risk (86) $ _____

Value of Equipment (other than vehicles) (87) $ _____

Value of Fire Department Facilities (88) $ _____

Effective Base Population (89) _____

Number of Active Runways (90) _____

Number of Housing Units (91) _____

Number of Fire Stations (92) _____

VEHICLES	NUMBER	VALUE ($)	AVAILABLE HRS
Total	(93) _____	(94) _____	(95) _____
Crash/Firefighting (P-15, P-2, P-4)	(96) _____	(97) _____	(98) _____
Structural Firefighting Pumpers (P-8, P-12)	(99) _____	(100) _____	(101) _____
Other (P-10, P-13, F-6, Pickups, P-6, Aerial)	(102) _____	(103) _____	(104) _____

Aircraft Value at Risk (105) $ _____ Aircraft Incidents (106) _____

Aircraft Loss (107) $ _____

Figure 5.1 Continued

After final approval, a cover letter recommending support of the effort was provided by Colonel George R. Tate, Director of Operations and Maintenance AFESC/DEM. The cover letter and request for information in Appendix F were sent from AFESC/DEM to all CONUS Air Force Fire Departments through their respective major commands. Data to be collected were for fiscal year 1983.

Data Collection Response. Seventy out of eighty-one active duty base fire departments and seven base fire departments operated by Air Force Reserves responded in the appropriate time period, and their data were subjected to an initial screening. Of those respondents, the seven Air Force Reserve operated fire departments were excluded from the data set because the authors felt their operations were not comparable to active duty fire department operations. Another seven data sets were not used because data were missing or because questionable data could not be confirmed by telephone. This left 63 bases with data sets appropriate for Constrained Facet Analysis use.

Cleansing the Data

Within the 63 data sets several data items were omitted or "cleansed" and several assumptions were made. The data information form in Figure 5.1 requested 107 data items. Of those, eight items were demographic information and points of contact for data confirmation and were not needed for CFA analysis.

A majority of respondents failed to report the "manhours" of the fire department outputs in items (9) through item (40) in Figure 5.1. Therefore, the authors did not use "manhours" but rather the actual "number" of outputs requested on the form.

The input items (64) through item (73) on the data information form requested "total" and "total available" manhours for each fire department branch. Several bases did not provide "total," and others provided "total" while also responding to "total available." In the latter case, the number of personnel was usually given instead of manhours. The manhour data reported most frequently was "total available" manhours. For those bases providing "total available" by number of personnel the following assumptions and calculations were made:

1) Management, Technical Services, and clerical employees work a 40-hour week.

2) Operations personnel work a 72-hour week.

3) All personnel work 48 weeks per fiscal year.

4) Item (65) "Total available Fire Department manhours" = (Total Fire department - Operations - Technical Services) x 40 hours per week x 48 weeks per year + item (67) + item (69)

5) Item (67) "Total available Operation manhours" = # Operations personnel x 72 hours per week x 48 weeks per year

6) Item (69) "Total available Technical Services manhours" = # Technical Services personnel x 40 hours per week x 48 weeks per year

Another variable omitted was item (86) "Industrial Structure Value at Risk ($)" because respondents interpreted the term "industrial" differently. The authors interpreted industrial structures as any building other than housing units. Item (86) was considered to be extraneous because item (34) "Real Property Value at Risk ($)" is available. To get the data requested in item (86) a simple mathematical subtraction operation is needed.

Also, in item (74) through item (83), the authors distinguished between "total" and "total available" personnel in various skill levels. Most responses had the same value in each. The authors confirmed by telephone that data for "total available" personnel was more accurate, and the "total" skill level items were deleted.

Other assumptions pertaining to the original data form include:

1) For item (63), "Contracted Services" expenditures, some bases did not provide a value, but did provide all other requested expenditure information. If this was the case, the authors assumed there were no contracted services and entered a value of zero for that response.

2) For "# Vehicle Available Hours" in items (93) through item (104), a 100% availability rate was assumed if no response was given.

3) For item (105), "Aircraft Value at Risk," a zero was assumed whenever values were not reported.

This left the 30 input and 42 output measures shown in Table 5.1 acceptable for editing, reconfiguring, and coding into the Constrained Facet Analysis format.

TABLE 5.1

Input/Output Data Set #1

INPUTS		OUTPUTS	
I1	Total # inspectors	O1	# Aerospace vehicle
I2	Civilian pay ($)	O2	Total # fire responses
I3	Military pay ($)	O3	# Housing fire responses
I4	Supply ($)	O4	# Other fire responses
I5	Equipment ($)	O5	# Fuel spill responses
I6	Contracted services ($)	O6	# Mutual aid responses
I7	Total available Fire Dept manhours	O7	# Other responses
I8	Total available Operations Branch manhours	O8	# Aircraft standbys
I9	Total available Technical Services Branch manhours	O9	# Other standbys
I10	Total available civilian manhours	O10	# Aircraft rescue drills
I11	Total available military manhours	O11	# Structural drills
I12	# Personnel in Skill level 57190	O12	# Classroom Training sessions
I13	# Personnel in Skill level 57170	O13	# Prime BEEF Training sessions
I14	# Personnel in Skill level 57150	O14	# Documents reviewed
I15	# Personnel in Skill level 57130 - 57110	O15	# In-service Documents reviewed
I16	# Personnel in Skill level 57100	O16	# Contract Documents reviewed
I17	Equipment value ($)	O17	Housing fire loss ($)
I18	Fire Dept facility value ($)	O18	Other fire loss ($)
I19	Total # vehicles	O19	Total fire loss ($)
I20	Value of I19	O20	Housing loss per reportable fire ($)
I21	Available hours of I19	O21	Other loss per reportable fire ($)

TABLE 5.1 Continued

INPUTS	OUTPUTS
I22 # Crash/firefighting vehicles	O22 Total loss per reportable fire ($)
I23 Value of I22 ($)	O23 # Housing inspections
I24 Available hours of I22	O24 # Other inspections
I25 # Structural pumpers	O25 Total # inspections
I26 Value of I25 ($)	O26 Base populace fire deaths
I27 Available hours of I25	O27 Firefighters deaths
I28 # Other vehicles	O28 Base populace fire injury
I29 Value of I28 ($)	O29 Firefighters injury
I30 Available hours of I28	O30 # Presentations on-base
	O31 # Presentations off-base
	O32 # Landings & takeoffs
	O33 Land area (acres)
	O34 Real property value
	O35 Housing value at risk
	O36 Effective base pop
	O37 # Active runways
	O38 # Housing units
	O39 # Fire stations
	O40 Aircraft value at risk ($)
	O42 Aircraft loss ($)

NOTE: Henceforth, all references to data elements will be by the input/output numbers contained in this table.

Preliminary Data Analysis

The preliminary data analysis includes the steps of editing and coding the data collected. Both of these two steps are discussed below.

Editing the Data. The first step in editing was to insure the input/output set fulfilled the conceptual belief that a change in output should be caused by a change in the inputs. This is called an "isotonic" relationship. For example, if an oganization is efficient an increase in inputs results in an increase in outputs, and a decrease in inputs should cause a decrease in outputs.

Reciprocal values were used for the output candidates in Table 5.2 to insure the existence of an isotonic relationship between the inputs and those outputs.

TABLE 5.2

Variables with Reciprocal Values

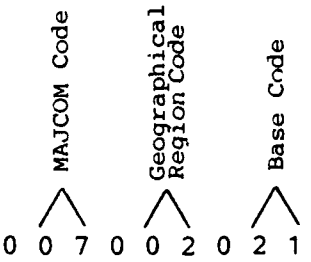
O17	Housing Building Fire Loss ($)
O18	Other Building Fire Loss ($)
O19	Total Building Fire Loss ($)
O20	Housing Loss per Reportable Fire ($)
O21	Other Loss per Reportable Fire ($)
O22	Total Loss per Reportable Fire ($)
O26	Base Populace Deaths
O27	Firefighter Deaths
O28	Base Populace Injuries
O29	Firefighter Injuries
O41	Aircraft Incidents
O42	Aircraft Loss ($)

Secondly, the data had to be appropriately scaled for the Constrained Facet Analysis code. The following two important aspects of the code had to be considered:

1) Measures that have values of 1,000,000 or more will create an overflow accompanied by the error message "illegal data in record number <x>." Thus, if any output or input measure that contains a value of 1,000,000 or more, the measures for all organizations must be scaled by some power of 10 so that all values of the output or input are less than 1,000,000. [13:6]

2) The user otherwise should not be concerned about ill conditioned data or data elements with observed zero values. Since solutions are invariant to scale, an automatic scale and descale routine has been incorporated in the CFA code for user convenience and computational ease. [13:6]

Coding the Data. After the appropriate data items were scaled, a nine digit organizational code unit identifier was given to each base to demographically separate the bases and to identify the bases by MAJCOM. An example of the unit identifier code is illustrated below.



The appropriate codes are found in Appendix F as part of the data collection instruction form.

The data was then keypunched on cards at the Air Force Institute of Technology Computer Center using the CFA format (13) described below. Cards 1 thru 14 were for the complete data set, followed by 63 sets of 12 cards for each Fire Department (Decision Making Unit).

CARD	DESCRIPTION	FORMAT
#1	"Problem Title"	12X,13A6,A2
#2	"Number of Organizational Units", "Number of Outputs", "Number of Inputs"	12X,3I5
Card Group #3 - #13	"Output 1 Label", "Output 2 Label", ... "Output 42 Label", "Input 1 Label", "Input 2 Label", ... "Input 30 Label"	12X,7A10
#14	Blank Card	-------
Card Group Set for each Fire Dept.	Identifier Record: "9 digit Organizational Unit Identifier", "Name of Fire Department"	2X,A10,6A10,A8
	Data Records: "9 digit Organizational Unit Identifier", Output measures for the Fire department followed by Input measures for the Fire Department	2X,A10,7F8.0

The complete data set found in Appendix G is shown in the Constrained Facet Analysis format, which enables the analysis to be executed.

Reduction of Input/Output Candidate List

At this point in the research process, the data on the input/output candidates is available and has been edited and coded for the Constrained Facet Analysis efficiency model.

Reduction of the data is now required to conform to the limitations of the Constrained Facet Analysis code.

If "n" is the total number of Decision Making Units (DMUs) or Fire Departments, then as a rule of thumb the CFA code will provide meaningful results if no more than n/2 input and output measures are used in the analysis. The initial list of candidate measures consisted of 63 DMUs with 72 input/output measures. According to the rule of thumb, the maximum number of input/output measures should be about 31. Several of the candidates represented the same fire department characteristic and could be used interchangeably. It was planned to interchange variables representing similar characteristics to determine which of these variables would best represent fire department objectives and operations.

This would also reduce the number of input/output variables to a manageable number that could consistantly be used in CFA in future analysis. A smaller number of input/output variables is preferred because analysis using a larger number is harder to interpret.

Reduction of Variables

The Constrained Facet Analysis code is currently on the TAURUS CDC Dual Cyber 170/750 mainframe computer at the University of Texas at Austin. It was necessary to go to University of Texas to learn the CFA software and to analyze the data. Drs. A. Bessent, W. Bessent, and T. Clark (10)

sponsored a Productivity Assessment Symposium at the University of Texas June 25 through 29, 1984. The symposium included discussion on CFA methodology with participants to update their understanding of productivity assessment techniques. The participants in the Productivity Assessment Symposium are shown in Appendix H.

The data set in Appendix G, consisting of 63 DMUs and 30 inputs and 42 outputs, was read into the Cyber. There were no problems with the data format. However, the authors were informed by Drs. A. Bessent and W. Bessent (10), supporters of the research and maintenance of the CFA code, that the code was currently dimensioned to handle no more than a total of 20 input/output measures per fire department. Dr. Authella Bessent tried to redimension the CFA code to analyze up to 100 inputs and outputs at one time, but her efforts were unsuccessful. Due to the inability to redimension the code, this research effort was affected as follows:

1) The authors were forced to reduce the data to more general categories.

2) A detailed analysis of subsets of measures could not be performed, for example ... Housing vs Total.

3) The simultaneous interaction of all fire department input and output measures could not be evaluated.

4) Recommendations to managers cannot be as detailed using general input and output measures; however, general recommendations for organizational improvements can be made and areas that require management to look at in more detail can be addressed.

The 20 input/output limitation was unforeseen; therefore, it became even more important to statistically reduce the total number of variables. The authors were faced with reducing the original 72 variables to 20 or less prior to CFA analysis, while still capturing Fire Department characteristics either directly or indirectly.

To aid in this reduction procedure, the Statistical Package of Social Sciences (SPSS) and its PEARSON CORRELATION subroutine was used. The authors analyzed outputs versus outputs, inputs versus inputs, and outputs versus inputs to determine the correlation between all 72 variables in Table 5.1.

In determining the strength of the relationship between variables, the PEARSON CORRELATION coefficient measures how well the value of one variable can be described on the basis of a knowledge of another variable. Therefore, the correlation coefficient measures the strength of correlation between two variables. Values close to zero indicate a weak relation; values close to +1.0 indicate a strong "positive" correlation; and values close to -1.0 indicate a strong "negative" correlation.

PEARSON CORRELATION Criteria for Variable Reduction.

The following criteria for variable reduction were considered in using the PEARSON CORRELATION values:

1) If a high positive correlation exists between any two input variables or any two output variables, then one of the factors is sufficient to measure the activity and the other can be discarded.

2) If a low correlation exists between an input variable and all output variables, then there is a weak relation between the variables; therefore, if the correlation values were close to zero the input variable was omitted from the analysis.

3) If a negative correlation between inputs and outputs exists, then the variable causing the negative correlation was omitted. Such negative correlations were interpreted to mean that additional amounts of the inputs tend to reduce outputs, a condition which violates the isotone property discussed on page 66.

Reduction #1. The initial PEARSON CORRELATION analysis resulted in changes to the data set. To reduce the variables, the authors 1) used data representing total quantities instead of their subsets; 2) combined like data, referred to as "collapsing" data; and 3) statistically reviewed the data again using Pearson Correlations to identify other possible reductions.

First, the authors used the total quantity values of a measure rather than its subset values. This decision reduces the detailed analysis the authors had hoped to provide managers. For example, "total building responses (O2)" was used instead of the subgroups of "housing building responses (O3)" and "other building responses (O4)". The complete list of variables using the total quantity measures is shown in Table 5.3.

TABLE 5.3

Variables using Total Quantity Measures

VARIABLE USED	VARIABLES DELETED FROM DATA SET
O2 Building Fire Responses	O3 Housing Fire Responses & O4 Other Fire Responses
O19 Building Fire Loss ($)	O17 Housing Fire Loss ($) & O18 Other Fire Loss ($)
O22 Total Loss per Reportable Fire ($)	O20 Housing Loss/Fire ($) & O21 Other Loss/Fire ($)
O25 Total # Inspections	O23 # Housing Inspections & O24 # Other Inspections

By using the total quantity variables in Table 5.3, the authors have decided not to differentiate between housing and other building responses and losses in any detail. To be consistent, the "# of housing units (O38)" and "housing

value at risk (O35)" will also be deleted from the variable list. Both of the above measures were surrogate measures for amount of protection provided to base housing units.

Second, the authors combined data representing similar fire department activities. For example, all fire department responses were combined or collapsed. Table 5.4 shows all the data collapsed to form one variable and the variables deleted from the data set.

At this point, the authors also subjectively omitted the "vehicle available hours (I21), (I24), (I27) and (I30)" from the data set. The authors had several none responses in these variables and had assumed 100% availability when the data were omitted. With this in mind, the accuracy of this data was questionable and therefore deleted from the data set.

TABLE 5.4

Variables Collapsed

NEW VARIABLE	VARIABLES COLLAPSED AND DELETED
O43 Responses	= O1 + O2 + O5 + O7
O44 Standbys	= O8 + O9
O45 Drills	= O10 + O11
O46 Documents Reviewed	= O14 + O15 + O16
O47 Presentations	= O30 + O31
I31 Expenditures	= I4 + I5 + I6

Furthermore, seven other variables were omitted from the data set:

1) "Mutual aid responses (O6)" was deleted because data did not represent all fire department mutual aid responses. The responses recorded at base level consisted of only responses to community fire departments. The reverse was not recorded.

2) The "number of active runways (O37)" was omitted because the authors felt the "total # of landings and takeoffs (O33)" was an adequate surrogate measure for aircraft at risk.

3) "Aircraft value at risk $ (O40)" was deleted because in most cases, the data was questionable or not present and could not be confirmed.

4) "Aircraft loss (O42)" was omitted since the "number of aircraft incidents (O41)" was deemed an adequate surrogate measure of aircraft loss and the data was more dependable.

5) "Loss per reportable fire (O22)" was not used because it was highly correlated with "total fire loss (O43)". Also, the authors believed "total fire loss" best represents how effective the fire department is once a fire is responded to.

6) "Total # inspectors (I1)" was deleted because "Technical Services manhours" also evaluates the use of personnel in the Technical Services Branch of the fire department.

7) "Fire related deaths to firefighters (O27)" was omitted because the PEARSON CORRELATION reflected the data did not affect fire department productivity. After a review of all data sets, it was found that all values were equal to zero.

These omissions reduced the data set from 72 input/output variables to 40 variables consisting of 23 inputs and 17 outputs. The reduced input/output list is shown in Table 5.5.

Reduction #2. The authors recombined variables again in an attempt to reduce the variables to an acceptable number. Considering the correlation values, an attempt to generalize categories representing similar fire department tasks was performed. The broader variables formed to directly or indirectly capture Fire Department activities are shown in Table 5.6.

The authors decided to use only "total number of vehicles (I19)" rather than dollar value of vehicles. Also, since the authors omitted variables that were breakdowns of total quantities, like housing and other structures, and used the total quantities instead, the same will be done with the vehicle breakdowns to maintain consistency. This decision omitted the variables in Table 5.7.

Although this reduction exceeds the 20 variable limit imposed by the CFA code, the authors settled on the 26 variables in Table 5.8 as the revised data set to input into

TABLE 5.5

Input/Output Data Set #2

INPUTS	OUTPUTS
I2 Civilian pay ($)	O43 Responses
I3 Military pay ($)	O44 Standbys
I7 Total available Fire Dept manhours	O45 Drills
I8 Total available Operations Branch manhours	O12 # Classroom Training sessions
I9 Total available Technical Services Branch manhours	O13 # Prime BEEF Training sessions
I10 Total available civilian manhours	O19 Total fire loss ($)
I11 Total available military manhours	O25 Total # Inspections
I12 # Personnel in Skill level 57190	O26 Base populace fire deaths
I13 # Personnel in Skill level 57170	O28 Base populace fire injury
I14 # Personnel in Skill level 57150	O29 Firefighters injury on-base
I15 # Personnel in Skill level 57130 - 57110	O47 Presentations
I16 # Personnel in Skill level 57100	O32 # Landings & takeoffs
I17 Equipment value ($)	O34 Real property value
I18 Fire Dept facility value ($)	O36 Effective base populace
I19 Total # vehicles	O39 # Fire stations
I20 Value of I19	O41 # Aircraft incidents
I22 # Crash/firefighting vehicles	
I23 Value of I22	
I25 # Structural pumpers	
I26 Value of I25	
I28 # Other vehicles	
I29 Value of I28	

TABLE 5.6

Variables Combined

O48 Drills/Training	= O45 + O12 + O13
O49 Deaths/Injuries	= O26 + O28 + O29
O50 Documents/Presentations	= O46 + O47
I32 Skill level Upper Mgmt.	= I12 + I13 + I16

TABLE 5.7

Vehicle Measures Deleted from the Data Set

I20 Value of total Fire Department vehicles

I22 # Crash/Firefighter vehicles	I23 Value of I22
I25 # Structural pumpers	I26 Value of I25
I28 # Other vehicles	I29 Value of I28

TABLE 5.8

Final Data Set Read into CFA Program

INPUTS	OUTPUTS
I2 Civilian pay ($)	O43 Responses
I3 Military pay ($)	O44 Standbys
I31 Supplies/Equipment ($)	O48 Training/Drills
I7 Total available Fire Dept manhours	O50 # Documents and presentations
I8 Total available Operation Branch manhours	O19 Total fire loss ($)
I9 Total available Technical Services Branch manhours	O49 Hurts (# deaths and injuries)
I10 Total available civilian manhours	O25 Total # inspections
I11 Total available military manhours	O34 Real property at risk ($)
I32 High skill level manhours	O32 # Landings & takeoffs
I14 Mid skill level manhours	O36 Effective base pop
I15 Low skill level manhours	O39 # Fire stations
I17 Equipment value ($)	O41 # Aircraft incidents
I18 Fire Dept facility value ($)	
I19 Total # vehicles	

the CFA program. Since the user of CFA can specify which inputs and outputs to be considered, and the CFA program read up to 30 variables (10), the data set in Appendix I consisting of the 26 variables in Table 5.8 was input into the CFA program.

The authors planned to interchange outputs and inputs to determine which measures provided the best results; however, another problem developed. Computer time and money provided by Drs. A. Bessent and W. Bessent at the University of Texas were limited; therefore, the authors could attempt only seven combinations of variables. To determine which variables to use, the authors attempted one final PEARSON CORRELATION.

Final Reduction. One final PEARSON CORRELATION was made in an attempt to reduce the number of variables acceptable to the CFA code. Variables reflecting a negative correlation between inputs and outputs were omitted.

The variables falling into the first category are listed below:

O19 Building Fire Loss ($)

O41 # Aircraft Incidents

O49 Hurts (# deaths and injuries)

The variables falling into the second category include:

O50 # Documents/Presentations

I17 Value of Equipment ($)

I18 Value of Fire Department Facilities ($)

Noting these exemptions, the variables remaining are listed in Table 5.9. The authors attempted seven test combinations of variables. To be consistent and to provide a basis of comparison, all eight output variables in Table 5.9 were used for each run. A breakdown of which inputs were used for each run with the eight outputs will be discussed in Chapter VI.

TABLE 5.9

Variables Selected for CFA Analysis

INPUTS	OUTPUTS
I2 Civilian pay ($)	O43 Responses
I3 Military pay ($)	O44 Standbys
I31 Supplies/Equipment ($)	O48 Training/Drills
I7 Total available Fire Dept manhours	O25 Total # inspections
I8 Total available Operation Branch manhours	O32 # Landings & takeoffs
I9 Total available Technical Services Branch manhours	O34 Real property at risk ($)
I10 Total available civilian manhours	O36 Effective base pop
I11 Total available military manhours	O39 # Fire stations
I32 High skill level manhours	
I14 Mid skill level manhours	
I15 Low skill level manhours	
I19 Total # vehicles	

AD-A146 874 MEASUREMENT OF AIR FORCE FIRE DEPARTMENT PRODUCTIVITY: AN EVALUATION OF E..(U) AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH SCHOOL OF SYST.. T A BYERS 2/3

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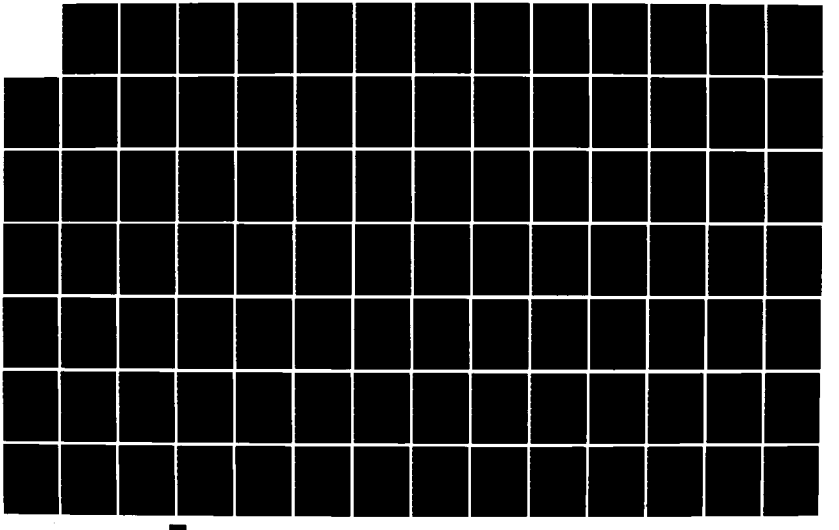

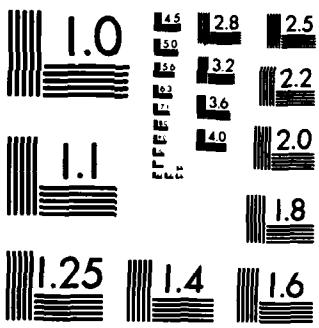
1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0
4.5
5.0
5.6
6.3
7.1

VI. Results and Analysis

This chapter will review the Constrained Facet Analysis (CFA) program execution, discuss the seven test runs analyzed by CFA and the problems encountered with each run, summarize the CFA errors encountered, and analyze the printouts and reports generated by CFA.

CFA Program Execution

Prior to discussing the results of each run attempted, a discussion of the executive commands for the code will be presented. After entry of the execution command, the code instructs the user to specify requirements of the analysis from five options.

First, the code asks which organizations are to be included in the reference set. The reference set is the set of Decision Making Units (DMUs) against which the units processed (specified in option 2) will be compared and analyzed for efficiency ratings. The authors requested all organizations be included in each test run.

Second, the code asks which DMUs of the reference set are to be processed. That is, which organizations does the user want analyzed and compared against the reference set. Again, the authors specified all organizations be processed. The user could analyze only one unit, or just a few, or all units.

The next two options ask which outputs and which inputs, respectively, are to be included in the analysis. The managerial reports available through the CFA code are the summary file, lambda file, and output file. Each are discussed later in this chapter. After the five options are specified, the program executes.

Multiple Input Multiple Output Tests Analyzed

The authors attempted seven separate runs using seven different combinations of inputs and outputs. Each run was a multiple input, multiple output model and each included the eight outputs listed in Table 5.9. Table 6.1 lists the input combinations used in each of the seven runs.

CFA Test Results

This section addresses the results and analysis of seven test runs (Tests 1 through 7) using the eight outputs in Table 5.9 and the different combinations of inputs in Table 6.1. For each test, the problems encountered and the limitations of the CFA code will be discussed. Of the seven tests only three were successfully completed (Tests 1, 4, and 5) while the other four produced errors that made the runs unsuccessful.

Test 1 Analysis. Test 1 evaluated eight outputs and five inputs. The five inputs included:

1) Supplies/Equipment
2) Vehicles
3) High Skill Level

TABLE 6.1

Input Combinations Attempted

Test 1	
I31	Supplies/Equipment
I19	Vehicles
I32	High Skill Level
I14	Mid Skill Level
I15	Low Skill Level

Test 2	
I31	Supplies/Equipment
I19	Vehicles
I2	Civilian Pay
I3	Military Pay

Test 3	
I31	Supplies/Equipment
I19	Vehicles
I7	Total Manhours
I8	Operations Manhours
I9	Technical Services Mhrs

Test 4	
I31	Supplies/Equipment
I19	Vehicles
I10	Civilian Manhours
I11	Military Manhours

Test 5	
I31	Supplies/Equipment
I19	Vehicles
I7	Total Manhours

Test 6	
I31	Supplies/Equipment
I19	Vehicles
I7	Total Manhours
I10	Civilian Manhours

Test 7	
I31	Supplies/Equipment
I19	Vehicles
I8	Operations Manhours
I9	Technical Services Mhrs

4) Mid Skill Level
5) Low Skill Level

The authors considered Test 1 the best indicator of fire department efficiency of the seven runs for two reasons. First, CFA appears to have successfully determined the efficient and inefficient fire departments in the data set (Appendix I). Second, by using the input measure "skill level" as a surrogate for total manpower, a manager can determine how well his organization is doing compared to similar units and can determine whether or not his mix of current skill levels needs revision. A more detailed analysis of the CFA output reports and their usefulness to a Fire Chief or manager will be discussed later in this chapter and in Chapter VII.

Test 2 Analysis. Test 2 substituted the two inputs "Civilian Pay (I2)" and "Military Pay (I3)" for the three skill level inputs used in Test 1. This particular run was unsuccessful. CFA analysis was incomplete because of potential unboundedness. This error results in cases where an extremely wide range of data values causes extremely small and extremely large computed values, which in turn cause ill-conditioned matrices and unbounded linear programming solutions. The ill-conditioned matrix problem which occurs during matrix inversion is a difficulty frequently encountered by linear programming codes.

Test 3 Analysis. Test 3 interchanged input variables "Civilian Pay (I2)" and "Military Pay (I3)" with "Total Fire

Department Manhours (I7)", "Operations Branch Manhours (I8)", and "Technical Services Branch Manhours (I9)". This run was also unsuccessful because of potential unboundedness. The input variables appear to be causing this error. The difference in size of each fire department inherently may be causing the large range of values in a variable. The matrix inversion problem is the same as found in Test 2, and appears to occur whenever "Total Manhours" is used in conjunction with its subsets.

Test 4 Analysis. Test 4 replaced the input variables total fire department, Operations, and Technical Services manhours with "Civilian Manhours (I10)" and "Military Manhours (I11)". This particular test run introduced another type of CFA error where negative right hand side values were introduced into the linear programming matrix causing CFA to cease analyzing certain fire departments. This error is also caused by one or more variables with very large range of values. However, the authors were able to build a CFA summary file and lambda file (to be discussed later in this chapter) by omitting the units CFA stopped processing due to the error. CFA analyzed each fire department up to the one where the negative right hand side value was introduced. When the error caused CFA analysis to stop, the authors reprogrammed CFA to analyze the fire departments starting immediately after the one where the error occured. This particular method produced meaningful

analytical results for 60 of the 63 fire departments in the reference set.

Test 5 Analysis. Test 5 evaluated eight outputs and three inputs. The three inputs were: 1) "Supply/Equipment (I31)", 2) "Vehicles (I19)", and 3) "Total Manhours (I7)". The effect of leaving out the manhour breakouts of the Operations and Technical Services Branch of Test 3 was a successful CFA run.

When the output file for this run was requested, the authors discovered that one of the units was given a zero lower bound efficiency rating. Management should carefully examine the data of the unit receiving the zero rating to determine if data errors caused the excessively low rating.

Test 6 and 7 Analysis. These two tests included the eight outputs used in the previous tests and four inputs. Test 6 used the inputs of Test 5 and added "Civilian Manhours (I10)". This test run was unsuccessful and produced a potential unboundedness error.

Test 7 was similar to Test 6 except the input variables total manhours and civilian manhours were replaced by the inputs "Operation Manhours (I8)" and "Technical Services Manhours (I9)". This run was also unsuccessful because of potential unboundedness. The authors hypothesize that when "total manhour" values are used in conjunction with their subelements the matrix inversion process becomes unbounded. The data collected in these variables have extremely large

ranges of values that CFA or other linear programs would find difficult to handle.

Summary of CFA Errors

The problems encountered with the CFA code are data related. A large range of values in the manhour variable appears to have caused the potential unboundedness errors. Any variable with a large range of values could cause the CFA code to stop processing the data set.

Two possible solutions to potential unboundedness are suggested below:

1) Reduce the reference set by including only those DMUs with data not having large ranges of values for a variable. The range can be examined statistically using the SPSS subroutine *CONDESCRIPTIVE*.

2) Divide all measures by one of the inputs. This would normalize the data (or shrink the range of the measure) and might alleviate the potential unboundedness error.

The other error was negative right hand sides. This error also appears to be caused by large ranges of measured values. The solutions mentioned above for potential unboundedness might solve this error as well.

Summary of Test Results

The three successful test runs (Tests 1,4, and 5), although different in some respects (input combinations

used), do show similarities. Each had approximately the same number of efficient and inefficient units, and each produced similar efficiency results. Comparative facet tables for Tests 1, 4, and 5 are contained in Appendix J. In the next section of this chapter a more detailed analysis of Test 1, and examples of the three different types of inefficiency conditions (fully enveloped, not fully enveloped, and outlier units) will be discussed.

Files Generated by the CFA Program

The constrained facet analysis results are provided in three files: the summary, lambda, and output (consisting of input and output change reports) files. The summary file provides the observed input and output values, the multipliers (see Chapter IV) and the slack value (see Chapter IV) for each fire department (DMU). An example of a summary file entry for DMU 33 is shown in Figure 6.1.

The lambda file lists all the inefficient DMUs, the efficient DMUs included in that unit's facet, and the associated lambda values (as described in Chapter IV). A sample lambda file entry for DMU 33 is shown in Figure 6.2.

The third available file is in two parts, the output change report and the input change report. For each DMU, the output change report provides values of each output which would cause the DMU to be rated efficient given that the current input levels are maintained. These output

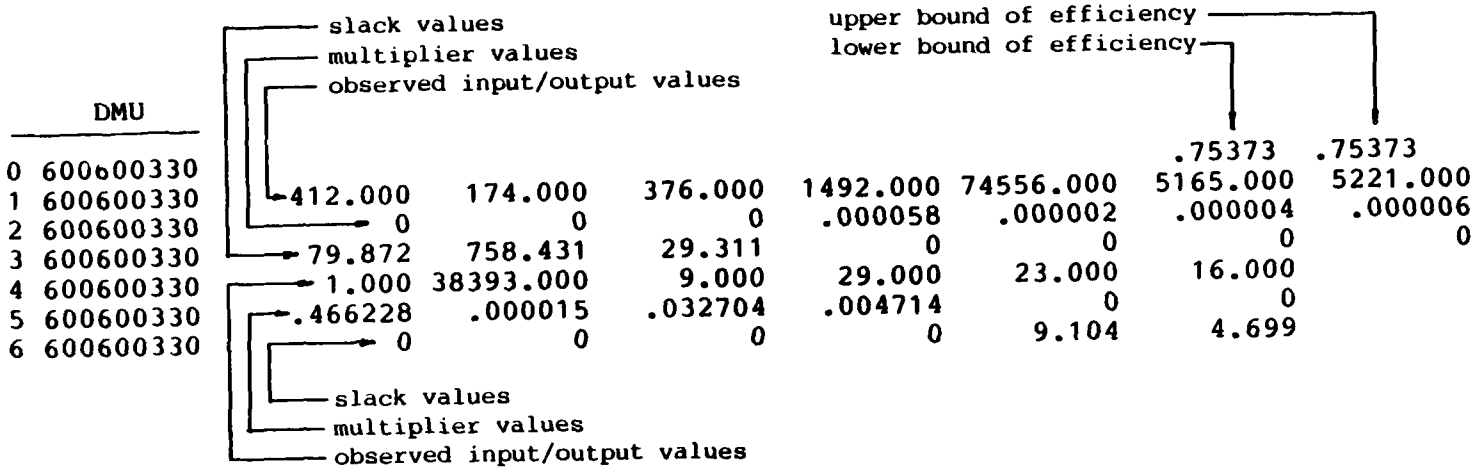

Figure 6.1 Sample Entry from CFA Summary File

Inefficient DMU	Efficient DMU	Lambda Values
1600600330	300700080	.33203
2600600330	300700120	.11638
3600600330	900500730	.03646
5600600330	200700020	.05644
6600600330	200500030	.06172
7600600330	700400400	-.04049

Figure 6.2 Sample Entry from CFA Lambda File

values are computed by multiplying the observed output amounts by the reciprocal of the lower bound efficiency measure. In a similar manner, the input change report provides input values which would cause the unit to be rated efficient given that output values are held constant. These values are computed by multiplying the current input values by the lower bound efficiency measure. In both reports, the percent contribution of each input and output measure to the efficiency of the DMU is also provided. The percentage is the product of the individual measurement multiplier and the measurement value. Figure 6.3 shows the output change report and Figure 6.4 shows the input change report for DMU 33. The lambda values for each DMU are printed at the end of the input change report for ease of reference.

Results of CFA Test 1

The remainder of this chapter will present the results of CFA for input/output Test 1. The summary file for this run is contained in Appendix K. It details the multiplier and slack value information for 35 efficient and 27 inefficient units. The upper and lower bound efficiencies for the inefficient units are shown in Table 6.2. Appendix L contains the lambda file for this run, the listing of facet members and associated lambda values for each inefficient unit.

To illustrate managerial use of the results of the CFA evaluation, three DMU's will be considered in depth, each

CFA MODEL OF EFF FOR AIR FORCE FIRE DEPT
DECISION MAKING UNIT 25 600600330

****
* SUMMARY OF RESULTS *
****

EFFICIENCY RANGE = 75.4 TO 75.4 PERCENT
MULTIPLIER FOR EFFICIENT OUTPUT LEVELS = 1.326

****
* OUTPUTS *
****

	OBSERVED VALUES	EFFICIENT OUTPUT LEVELS	PERCENT CONTRIBUTIONS TO EFFICIENCY
RESPONSES	412.0	626.4	0
STANDYBYS	174.0	989.2	0
TRAINING	376.0	528.1	0
INSPNS	1492.0	1979.1	8.7
L AND T	74556.0	98895.4	14.8
RP RISK	5165.0	6851.2	2.2
POP	5221.0	6925.4	3.1
STATIONS	1.0	1.3	46.6
		TOTAL :	75.4 PERCENT

Figure 6.3 Sample Entry from CFA Output Change Report

****
* INPUTS *
****

	OBSERVED VALUES	NO INPUT CHANGES REQUIRED	RELATIVE IMPORTANCE OF INPUTS
SUPP/EQP	38393.0		56.9
HI MHRS	9.0		29.4
MID MHRS	29.0		13.7
LO MHRS	23.0		0
VEHICLES	16.0		0
			TOTAL : 100.0 PERCENT

Figure 6.3 Continued

CFA MODEL OF EFF FOR AIR FORCE FIRE DEPT
DECSION MAKING UNIT 25 600600330

****
* SUMMARY OF RESULTS *
****

EFFICIENCY RANGE = 75.4 TO 75.4 PERCENT
MULTIPLIER FOR EFFICIENT INPUT LEVELS = .754

****
* OUTPUTS *
****

	OBSERVED VALUES	NO OUTPUT CHANGES REQUIRED	PERCENT CONTRIBUTION TO EFFICIENCY
RESPONSES	412.0		0
STANDBYS	174.0		0
TRAINING	376.0		0
INSPNS	1492.0		8.7
L AND T	74556.0		14.8
RP RISK	5165.0		2.2
POP	5221.0		3.1
STATIONS	1.0		46.6
		TOTAL :	75.4 PERCENT

Figure 6.4 Sample Entry from CFA Input Change Report

****
* INPUTS *
****

	OBSERVED VALUES	EFFICIENT INPUT LEVELS	RELATIVE IMPORTANCE OF INPUTS
SUPP/EQP	38393.0	28937.8	56.9
HI MHRS	9.0	6.8	29.4
MID MHRS	29.0	21.9	13.7
LO MHRS	23.0	8.2	0
VEHICLES	16.0	7.4	0
		TOTAL :	100.0 PERCENT

CFA MODEL OF EFF FOR,AIR FORCE FIRE DEPT
DECSION MAKING UNIT 25 600600330

****
****

X	300700080	.33203
X	300700120	.11638
X	900500730	.11459
X	900600710	.03646
X	200700020	.05644
X	200500030	.06172
X	700400400	-.04049

Figure 6.4 Continued

TABLE 6.2

Bounds of Efficiencies for Inefficient Units

Organization (DMU)	Efficiency	
	Lower Bound	Upper Bound
1	.66562	.68137
17	.49013	.80792
20	.51300	.87716
23	.70716	.70716
24	.57660	.68262
31	.67728	.71226
32	.54864	.54864
33	.54037	.75373
34	.49499	.60591
37	.46016	.58693
39	.54844	.90707
41	.82956	.88555
43	.67099	.98074
48	.66644	.66644
49	.59317	.74958
51	.50039	.76143
52	.73909	.90669
54	.44634	.55918
55	.63301	.67861
56	.69906	.71078
57	.70317	.94919
59	.37655	.68892
61	.52847	.70674
63	.33539	.95237
64	.65618	.98060
70	.60687	.83235
72	.60174	.70955

illustrating a different level of envelopment. In each consideration, the following properties of the CFA model should be kept in mind. A DMU will have an efficiency of 1.00 only when:

(a) None of its outputs can be increased without either
    (i) Increasing one or more of its inputs or
    (ii) Decreasing some of its other outputs

(b) None of its inputs can be decreased without either
    (i) Decreasing some of its outputs or
    (ii) Increasing some of its other inputs.

[17:2]

CFA Results for DMU 48. As noted in Chapter IV, a DMU efficiency rating developed by CFA is relative to other DMUs in a facet. The lower bound efficiency for DMU 48 is .66644 and the upper bound is also .66644. The fact that the values are equal and that there are 12 efficient units in the facet (number of inputs + number of outputs + 1) indicates that the unit is fully enveloped. Table 6.3 shows data for DMU 48 and for the efficient DMUs in its facet. The entries were developed by dividing all measured values of each DMU in the table by that DMU's measured value for the number of vehicles. This procedure effectively scales the input and output measures for ease of comparison. The scaling in no way affects the efficiency ratings described in Chapter IV and Appendix D. Table 6.4 shows multiplier values for this unit and the DMUs in its proper facet. The full envelopment of DMU 48 is evident when its measurement values are compared to the range of values for the facet in

TABLE 6.3

Fire Department 48 Observed Values per Vehicle
Compared with Observed and Average Values per Vehicle
of Efficient Fire Departments

DMU	Vehicle (I19)	Respons (O43)	Standby (O44)	Traing (O48)	Inspect (O25)	L and T (O32)	RP Risk (O34)
3	1 (17)	137.29	158.11	48.64	576.29	8247.94	1740.76
11	1 (15)	76.80	138.93	35.66	54.13	32359.86	479.53
16	1 (14)	68.35	2.85	83.28	88.28	44038.64	594.07
21	1 (7)	90.85	5.28	168.85	395.14	1.57	727.00
38	1 (18)	75.27	35.72	96.66	123.72	12333.33	1284.66
44	1 (13)	40.76	116.30	82.76	256.53	3376.92	47975.84
53	1 (14)	47.14	89.00	175.92	324.28	4436.14	5082.07
60	1 (15)	59.53	11.40	132.00	250.40	3603.86	1582.86
62	1 (12)	165.08	66.41	41.16	107.83	2324.08	521.41
65	1 (15)	124.73	155.60	119.06	117.86	3715.33	18611.60
66	1 (18)	52.44	47.60	269.16	58.05	3748.16	375.44
67	1 (16)	193.43	67.37	24.25	125.12	9307.06	1004.62
AVE	1 (14.5)	94.30	74.54	106.45	206.46	10624.40	6664.98
48	1 (12)	56.08	12.91	124.25	193.16	1741.16	780.91

DMU	Pop (O36)	Station (O39)	Sup/Eqp (I31)	Hi SL (I32)	Mid SL (I14)	Low SL (I15)
3	1212.00	.11	4892.41	.88	3.82	1.00
11	226.66	.06	13336.80	.53	3.33	.46
16	750.00	.14	14360.28	1.07	2.14	.92
21	371.42	.14	4000.00	.71	3.57	.85
38	892.44	.27	15542.72	.50	1.83	.61
44	84.61	.07	17045.61	.76	2.15	.15
53	678.57	.07	14243.21	.50	3.21	.71
60	3289.90	.13	11971.53	.53	4.00	.60
62	693.16	.08	12167.58	.58	3.25	.75
65	822.46	.13	10383.33	1.20	3.00	.33
66	600.00	.05	4239.66	.77	.50	1.05
67	793.75	.12	10376.75	1.06	2.68	.62
AVE	867.90	.11	11046.65	.75	2.79	.67
48	542.25	.08	9236.50	.75	3.08	.83

TABLE 6.4

Multiplier Values for the Proper Facet of Fire Department 48

DMU	Respons (O43)	Standby (O44)	Traing (O48)	Inspect (O25)	L and T (O32)	RP Risk (O34)	Pop (O36)
3	.000249	.000056	.000010	.000007	.000001	.000001	.000000
11	.000342	.000196	.000010	.000000	.000000	.000001	.000000
16	.000160	.000001	.000010	.000012	.000001	.000001	.000000
21	.000360	.000232	.000455	.000079	.000002	.000001	.000000
38	.000194	.000001	.000029	.000000	.000001	.000001	.000002
44	.000174	.000122	.000010	.000026	.000000	.000001	.000000
53	.000367	.000001	.000228	.000018	.000000	.000001	.000005
60	.000000	.000001	.000010	.000000	.000000	.000001	.000019
62	.000422	.000015	.000228	.000000	.000001	.000001	.000000
65	.000294	.000013	.000010	.000000	.000000	.000001	.000000
66	.000287	.000039	.000143	.000000	.000000	.000001	.000000
67	.000261	.000001	.000010	.000000	.000000	.000001	.000011
48	.000356	.000001	.000211	.000024	.000001	.000001	.000004

DMU	Station (O39)	Sup/Eqp (I31)	Vehicle (I19)	Hi SL (I32)	Mid SL (I14)	Low SL (I15)
3	.000010	.000001	.053428	.000323	.000010	.000010
11	.000010	.000001	.000010	.109554	.000010	.000010
16	.170696	.000001	.055477	.000010	.000010	.000010
21	.000010	.000005	.000010	.078195	.000010	.078965
38	.102152	.000002	.000010	.018804	.005372	.000010
44	.000010	.000003	.000010	.000010	.013654	.000010
53	.000010	.000000	.040834	.055406	.000010	.000010
60	.000010	.000004	.000010	.004243	.000010	.030440
62	.000010	.000000	.061240	.035720	.000010	.000010
65	.000010	.000002	.004211	.031105	.000010	.015708
66	.000010	.000002	.000010	.062401	.000010	.000010
67	.000010	.000002	.045328	.000010	.000010	.000010
48	.017747	.000000	.045457	.036381	.000577	.009204

Table 6.3. The values for DMU 48 are always within the range, never being the highest or lowest entry.

CFA Results for DMU 63. DMU 63 illustrates another type of unit, the outlier. The lower bound efficiency for this unit is .33539 (the lowest in the set), the upper bound is .95237 and there are only eleven efficient units in its facet. Table 6.5 shows the measures per vehicle for each efficient DMU in the facet along with the measures per vehicle for DMU 63. Note that the standbys per vehicle and supplies/equipment per vehicle for DMU 63 were higher than any in the facet and the real property at risk per vehicle and stations per vehicle were lower than any in the facet. The fact that these values are near the upper or lower limit of values in the facet identifies that the values of DMU 63 are outliers and that DMU 63 is an outlier unit. The multipliers for this facet, shown in Table 6.6, show how the model minimized the effect of the low output value for real property at risk and the high input value for supplies and equipment by assigning multiplier values near zero in order to achieve the highest efficiency rating possible. Without more in-depth analysis of this unit, it is impossible to determine if the actual efficiency is in the lower or upper portion of the efficiency range.

The presentation of values in Table 6.5 also points out the effect on the model of incorrect data elements. The values for high, mid and low skill level personnel for DMU 4

TABLE 6.5

Fire Department 63 Observed Values per Vehicle
Compared with Observed and Average Values per Vehicle
of Efficient Fire Departments

DMU	Vehicle (I19)	Respons (O43)	Standby (O44)	Traing (O48)	Inspect (O25)	L and T (O32)	RP Risk (O34)
2	1 (19)	60.26	110.84	60.53	318.42	6542.63	852.74
3	1 (17)	137.29	158.12	48.65	576.29	8247.94	1740.76
4	1 (16)	7.93	8.81	26.12	165.50	5250.00	1336.62
9	1 (7)	53.14	0.00	31.43	273.86	1.86	1516.57
14	1 (17)	41.24	25.53	38.82	119.06	45100.57	1013.82
30	1 (12)	35.25	189.25	72.75	109.16	5012.33	1022.75
44	1 (13)	40.76	116.30	82.76	256.53	3576.92	47975.84
60	1 (15)	59.53	11.40	132.00	250.40	3603.86	1582.86
65	1 (15)	124.73	155.60	119.06	117.86	3715.33	18611.60
69	1 (18)	127.27	248.11	78.11	132.00	10444.44	1129.94
73	1 (14)	85.29	81.79	51.14	190.50	261.36	827.86
AVE	1	76.47	109.69	71.52	234.40	8650.72	7627.47
63	1 (15)	50.00	313.53	26.86	115.33	4973.80	741.13

DMU	Pop (O36)	Station (O39)	Sup/Eqp (I31)	Hi SL (I32)	Mid SL (I14)	Low SL (I15)
2	1453.32	.26	8633.11	.74	3.05	1.26
3	1212.00	.12	4892.41	.88	3.82	1.00
4	1210.37	.12	12186.62	0	0	0
9	2571.43	.14	5645.29	1.57	3.86	.86
14	706.53	.06	4477.76	.65	2.35	.18
30	2032.58	.08	8877.58	1.08	3.00	.08
44	84.61	.07	17045.61	.76	2.15	.15
60	3289.80	.13	11971.53	.53	4.00	.60
65	822.46	.13	10383.33	1.20	3.00	.33
69	2222.22	.11	10279.72	.94	3.00	.72
73	773.14	.07	13.57	1.29	2.29	.36
AVE	1516.80	.11	8221.99	.96	3.05	.55
63	1555.26	.06	41199.06	.86	2.80	.26

TABLE 6.6

Multiplier Values for the Proper Facet of Fire Department 63

DMU	Respons (O43)	Standby (O44)	Traing (O48)	Inspect (O25)	L and T (O32)	RP Risk (O34)	Pop (O36)
2	.000031	.000001	.000022	.000036	.000000	.000001	.000000
3	.000249	.000056	.000010	.000007	.000001	.000001	.000000
4	.000000	.000154	.000010	.000071	.000001	.000001	.000013
9	.000115	.000001	.000010	.000078	.000002	.000003	.000042
14	.000000	.000001	.000010	.000004	.000002	.000001	.000022
30	.000000	.000194	.000010	.000050	.000001	.000001	.000016
44	.000174	.000122	.000010	.000026	.000000	.000001	.000000
60	.000000	.000001	.000010	.000000	.000000	.000001	.000019
65	.000294	.000013	.000010	.000000	.000000	.000001	.000000
69	.000091	.000034	.000010	.000000	.000000	.000001	.000015
73	.000000	.000001	.000010	.000367	.000000	.000001	.000000
63	.000017	.000012	0	.000011	.000000	.000000	.000006

DMU	Station (O39)	Sup/Eqp (I31)	Vehicle (I19)	Hi SL (I32)	Mid SL (I14)	Low SL (I15)
2	.127667	.000003	.000010	.002319	.007811	.000010
3	.000010	.000001	.000010	.109554	.000010	.000010
4	.214634	.000000	.061156	.000010	.019977	.000010
9	.020104	.000006	.011494	.000010	.025507	.000010
14	.000010	.000000	.038923	.011128	.000010	.069294
30	.000010	.000007	.000010	.018485	.000010	.043490
44	.000010	.000003	.000010	.000010	.013654	.000010
60	.000010	.000004	.000010	.004243	.000010	.030440
65	.000010	.000002	.004211	.031105	.000010	.015708
69	.000010	.000003	.000010	.013730	.002558	.000010
73	.000010	.002262	.000010	.031647	.000010	.000010
63	.066333	.000001	.005164	.000618	.002316	.009382

were zero since the values could not be ascertained at the time the data was processed. Since these values made up a large portion of the input measures, the ultimate effect was to make unit 4 efficient when in actuality it may not have been. With the knowledge that this unit may not be a valid facet member, its values were not included in the average figures.

CFA results for DMU 33. DMU 33 illustrates still another aspect of the CFA analysis. The lower bound efficiency was .54037, the upper bound was .75373, and the number of units in its facet was seven. The unit is not enveloped and the basis is incomplete which leads to non-zero slack/surplus values in five variables. The values indicated in the summary file for unit 33 (shown in Figure 6.1) are derived on the first iteration of the CFA linear programming model and represent the adjustment required at this point to force the unit to be efficient. Particularly noticeable for unit 33 is the slack value of 14303.698 compared to the variable value of 5165.00 for real property at risk. Obviously this is a nondiscretionary variable and any adjustments to improve efficiency would have to take place in some other area.

The data for the facet of DMU 33 shown in Table 6.7 and the multipliers shown in Table 6.8 illustrate the manner in which CFA attempts to ignore or minimize outlier values. This was especially noticeable in the zero multipliers

TABLE 6.7

Fire Department 33 Observed Values per Vehicle
Compared with Observed and Average Values per Vehicle
of Efficient Fire Departments

DMU	Vehicle (I19)	Respons (O43)	Standby (O44)	Traing (O48)	Inspect (O25)	L and T (O32)	RP Risk (O34)
2	1 (19)	60.26	110.84	60.53	318.42	6542.63	852.74
3	1 (17)	137.29	158.12	48.65	576.29	8247.94	1740.76
8	1 (6)	45.17	1.33	62.67	138.67	0	378.67
12	1 (15)	24.60	280.73	56.80	8.07	33821.40	429.33
40	1 (16)	35.12	91.19	92.00	121.31	1140.63	977.13
71	1 (15)	66.20	151.40	78.47	52.20	240.00	411.73
73	1 (14)	85.29	81.79	51.14	190.50	261.36	827.86
AVE	1 (14.6)	64.84	125.05	64.32	200.78	7179.13	802.60
33	1 (16)	25.75	10.88	23.50	93.25	4659.75	322.81

DMU	Pop (O36)	Station (O39)	Sup/Eqp (I31)	Hi SL (I32)	Mid SL (I14)	Low SL (I15)
2	1453.32	.26	8633.11	.74	3.05	1.26
3	1212.00	.12	4892.41	.88	3.82	1.00
8	511.16	.17	2521.50	1.17	3.17	1.67
12	216.47	.13	6770.40	.67	2.27	1.13
40	728.19	.19	3567.00	1.25	2.44	.63
71	413.47	.07	0	.60	4.07	.67
73	773.14	.07	13.57	1.29	2.29	.36
AVE	758.25	.14	1077.46	.94	3.01	.96
33	326.31	.06	2399.56	.56	1.81	1.44

TABLE 6.8

Multiplier Values for the Proper Facet of Fire Department 33

DMU	Respons (O43)	Standby (O44)	Traing (O48)	Inspect (O25)	L and T (O32)	RP Risk (O34)	Pop (O36)
2	.000031	.000001	.000022	.000036	.000000	.000001	.000000
3	.000249	.000056	.000010	.000007	.000001	.000001	.000000
8	.000592	.000001	.000116	.000000	.000000	.000001	.000000
12	.000383	.000014	.000147	.000000	.000001	.000001	.000000
40	.000219	.000001	.000023	.000000	.000000	.000002	.000003
71	.000986	.000001	.000010	.000000	.000000	.000001	.000000
73	.000000	.000001	.000010	.000367	.000000	.000001	.000000
33	.000200	.000027	0	0	.000001	0	.000003

DMU	Station (O39)	Sup/Eqp (I31)	Vehicle (I19)	Hi SL (I32)	Mid SL (I14)	Low SL (I15)
2	.127667	.000003	.000010	.002319	.007811	.000010
3	.000010	.000001	.053428	.000323	.000010	.000010
8	.793427	.000014	.131118	.000010	.000010	.000010
12	.000010	.000003	.000010	.066070	.000010	.000010
40	.261083	.000004	.000010	.009216	.014218	.002733
71	.000010	.099905	.000010	.000010	.000010	.000010
73	.000010	.002262	.000010	.031647	.000010	.000010
33	.341173	.037674	.000009	.006887	0	0

assigned in Table 6.8 for training, inspections, real property at risk, mid skill level, and low skill level.

DMU Relative Efficiencies

It has been shown how important it is to have complete information about the efficient units in a facet in order to draw conclusions about the inefficient unit. Additional conclusions about efficient (frontier) units can be drawn by considering the number of appearances of those units in the facets of inefficient ones. Table 6.9 shows the number of appearances of each efficient DMU in the facet of an inefficient DMU.

Note that units 13, 25, 46 and 47 do not appear in any facet of any inefficient unit. It is thus possible to comment that these units may not actually be efficient, but appear to be so only because of special descriptive features. On the other hand, unit 44 appears in the facets of 25 of the 27 inefficient units, strong evidence of its relative efficiency. This information is useful for management in analyzing the effect that DMU behavior has on the efficiency of other units and also in determining relative optimal combinations of measurement values.

The next chapter will introduce the manager's use of the input and output change reports and describe a proposal to integrate CFA into a Civil Engineering automated management system.

TABLE 6.9

Number of Appearances of each Efficient DMU in the Facet of an Inefficient DMU (Test #1)

Inefficient Units \ Efficient Units	2	3	4	7	8	9	10	11	12	13	14	15	16	21	22	25	30	35	36	38	40	42	44	45	46	47	53	60	62	65	66	67	69	71	73	23*
1	X			X		X										X					X		X					X					X	X	
17		X	X	X					X						X					X			X				X	X				X			X
20	X	X	X						X					X	X		X				X							X		X	X		X			
23*																							X								X			X	X	
24	X	X		X		X																	X					X		X	X		X		X	X
31		X		X					X				X							X			X				X	X		X	X		X			
32			X					X						X	X			X		X			X					X	X	X	X		X			
33	X	X			X				X												X													X	X	
34	X	X		X					X				X							X			X					X		X	X		X			
37	X	X					X		X		X		X	X						X	X		X							X	X					
39		X	X						X								X				X		X					X		X	X		X		X	
41			X	X					X						X			X		X			X				X	X			X		X			X
43		X	X					X						X	X					X			X				X	X	X		X		X			
48		X						X					X	X						X			X				X	X	X	X	X	X				
49		X	X					X	X		X		X					X						X				X		X	X		X			
51	X	X	X				X		X		X		X							X	X		X								X				X	
52		X	X	X					X			X								X			X				X	X			X		X			X
54	X			X										X	X						X		X					X		X	X			X		
55		X	X					X												X			X				X	X	X	X	X	X	X			
56		X				X			X														X					X		X	X		X	X	X	X
57		X	X					X						X	X					X			X				X	X	X		X		X			
59	X	X	X	X													X			X			X					X		X			X			
61		X	X	X													X				X		X					X		X	X		X		X	
63	X	X	X			X					X						X						X					X		X			X		X	
64		X					X		X		X		X						X				X							X	X	X			X	
70		X	X									X								X			X							X	X	X	X			X
72			X	X										X	X					X			X	X							X					
Total	10	21	16	11	1	4	3	6	13	0	5	2	7	8	8	1	5	3	1	15	8	0	25	1	0	0	8	20	5	17	22	4	18	5	10	6

* Due to a CFA code idiosyncracy, this unit appears in both the efficient and inefficient sets.

VII. Air Force Fire Protection Automated Management System

This chapter develops the use of the results of Constrained Facet Analysis (CFA) by the individual Fire Chiefs and by the Major Commands and also discusses the integration of CFA into a Civil Engineering automated management system.

Use and Distribution of CFA Results

The products generated by CFA provide management information for all levels in Civil Engineering. The summary and lambda files are most useful at MAJCOM and Air Staff levels. Here broad evaluations of efficiency and effectiveness can be applied across base and MAJCOM organizational boundaries. As stated in the problem statement in Chapter I, efficiency is not the only criterion of interest in the management of fire departments. Effectiveness goals must also be addressed. Perhaps several fire departments, including some of the frontier units, have been producing levels of output which are considered to be too low by managers. Perhaps goals should be established in an attempt to increase levels of achievement of units, thus improving their effectiveness.

Effectiveness, as defined in Chapter I, is the ability of an organization to attain its goals. In the case of Air Force Fire Departments, this involves mission support as

specified in both the strategic (long-range) and tactical (short-range) planning processes. The Fire Department, as any military organization, should use this process to set its long-range goals and the short-range goals that support them. To achieve the desired results, the Fire Chief should guide and lead the department's members indirectly toward the establishment and achievement of these lower level goals. The long-range goal of constructing a new fire station, staffing it, and equipping it with apparatus would require yearly strategic and operational goals by MAJCOMs. Decisions about features of specific pieces of apparatus and for equipment to go in the new station, based on past and projected record of fire department activities, are required sometimes in a short period of time.

In order for a fire department to operate effectively and efficiently, personnel should be selected and allocated where needed to take advantage of the new employees' abilities and leadership. Likewise, vehicles and equipment should be allocated to organizations that can benefit the most. CFA provides a way to look at the total labor force and identify efficient and inefficient units so MAJCOMs can allocate senior noncommissioned officers (NCOs) to inefficient units, even though an efficient fire department may also need an NCO. Presently, allocation of this resource is an opinionated evaluation performed by Major Command managers.

Vehicles are allocated based on age and mission of the fire department. Managers at the MAJCOM are provided input from an automated tool referred to as the Vehicle Integrated Management System (VIMS) maintained by the Transportation Branch. VIMS forecasts vehicle replacements based on the factors listed above. After VIMS identifies old vehicles to be replaced or new vehicles available for distribution to fire departments, MAJCOM managers employ individual subjective evaluations and decisions on who gets the new vehicles. If MAJCOMs had the CFA results indicating the role of vehicles in the efficiency of a unit, their decisions could be more objective and justifiable.

The output product consisting of the input and output change reports is published for and distributed to the DMU manager, in this case the individual Fire Chief. The report provides the following information:

- the efficiency rating of the Fire Department
- the input and output values used for the analysis of the unit
- the ouput values needed to attain efficiency of 1.00 if current inputs are maintained
- the input values needed to attain efficiency of 1.00 if current outputs are maintained
- the relative contributions of individual outputs and inputs to the lower bound efficiency rating
- the identification of the efficient departments that have input levels similar to that Fire Department

The Fire Chief then can set his own management goals and be aware of the departments from which to gain information on improving his efficiency.

Automated Management System

In order to manage its fire protection program, the Air Force is faced with the problem of measuring the adequacy of its fire protection resources. Traditionally, this measurement has been fragmented. A variety of methods have been used, including Major Command Staff visits, Inspector General visits and a diverse range of reporting procedures. In general, these have been less than totally satisfactory (29:1).

The Air Force Fire Protection Program needs a system that will provide improved fire protection measurement. Ultimately, the goal is to provide decision makers at all levels in the program with improved information on which to base decisions relative to future directions for Air Force fire protection. Three goals at the individual installation level include:

1) provide an objective evaluation of the installation fire protection program based on actual measures of inputs and outputs;

2) identify specific deficiencies at specific Air Force installations and provide relative priorities for corrective action; and

3) recommend corrective actions for identified deficiencies.

The goals at Major Command and Air Force Headquarters level should include:

1) provide the summary information regarding overall fire protection status;

2) collect data from the system that would indicate program trends when accumulated over a period of time; and

3) know the status and trends relative to existing fire protection requirements and know which fire departments were relatively inefficient compared to others with similar input/output mix. This information would provide the basis for:

a) fire protection budget requests and justification;

b) redistribution of fire protection resources (e.g., vehicles and manpower) where imbalances are detected;

c) modifying and clarifying fire protection requirements when it becomes apparent that such action is warranted.

Finally, such a system would provide a structured base of information relative to existing and projected fire protection resources that could be correlated with actual fire incident experience. By jointly analyzing Fire Department efficiencies and goals, it would be possible

to more accurately evaluate the various fire protection alternatives. Again, the end result would be an improved basis for management decisions affecting Air Force fire protection.

The integration of CFA into the management system would provide broad based information on most aspects of both efficiency and effectiveness. Uses of the CFA-based system include fire department profiles, contingency planning and annual reviews where MAJCOMs can monitor trends that will be beneficial in allocating resources to fire departments.

Fire Department Profiles. In addition to the reports which are routinely operated by base level users, the MAJCOMs can use the system to search for fire departments in the data base which have any specified input and output characteristics and they will be able to generate fire department profiles. The profiles will include the distribution of input, output and efficiency ratings for fire departments which will indicate how each department's resources, effectiveness and efficiency compare to other fire departments in the same command and to those Air Force wide.

Contingency Planning. Another area where a CFA-based system can help MAJCOM planners is its use in wartime and contingency planning. A MAJCOM can manipulate the input and output measures to reflect changes in contingency situations and forecast efficient and inefficient fire departments. In

this situation all military will leave the CONUS base, aircraft sorties will increase or decrease, base missions will change, and other measures will change depending on the installation's wartime commitment. After the wartime scenario is established and CFA applied, one can determine where resources need to be reallocated to improve efficiency ratings at CONUS fire departments.

Annual Reviews. Finally, the MAJCOMs will be able to review fire departments on an annual review basis. The annual review process will provide a comprehensive method for monitoring the status and trends of the total Air Force Fire Protection Program. MAJCOMs will be able to obtain information regarding the allocation and distribution of scarce resources to fire departments. Some of the questions that can be answered using information from the proposed system include (12:3):

- How well are fire departments meeting goals?
- What distribution of scarce resources would result in the best overall service levels?
- Given existing resource availability, what level of services can be accomplished?

Conclusion

CFA analysis of a Fire Department has been shown to provide valuable information for the Fire Chief in improving both his efficiency and effectiveness. The extension of this method into an integrated automated management system

presents an opportunity for Civil Engineering managers at every level of management to use information and analysis from several data sources to develop the optimal productivity improvement strategy. Thus, the best use of CFA analysis results for each level of management has been proposed and the fourth research question answered.

VIII. Conclusions and Recommendations

This chapter presents the conclusions and recommendations of this research. The conclusion restates the research problem and then summarizes the results of each research objective. The effects of the CFA model's limitations will be presented in this chapter, along with recommendations to improve the CFA efficiency model for fire departments.

Conclusions

The Air Force Engineering and Services Center (AFESC) has supported this research to find an efficiency model that will measure fire department efficiency. Measuring the efficiency of Air Force fire department performance is a complex problem because of its multiple input, multiple output characteristics and because of a lack of quantitative measures.

Research Objective 1

A comprehensive set of input/output candidates were selected using the list of tasks developed at the AFESC Fire Department functional review workshop. The data form developed to collect information from CONUS Base Fire Departments was reviewed for adequacy, completeness, and data availability by Air Force fire protection experts.

Fiscal year 1983 data from 81 bases was collected with the sponsorship of HQ AFESC through the CONUS Major Command's.

Research Objective 2

The research reviewed linear regression and ratio analysis and determined that neither can correctly identify inefficiencies within multiple output, multiple input organizational units. These models cannot capture the interactions between inputs and outputs. However, a new approach, Constrained Facet Analysis (CFA), has been developed that does take into account simultaneously the relationship of multiple inputs and multiple outputs using empirical data. It was therefore determined that CFA was apparently the best model to analyze Fire Department performance. Once the CFA model was selected for use, the data could be prepared for analysis.

When the data forms were returned to the authors, they were screened for completeness and validity. The data from the 63 remaining organizations, consisting of 42 outputs and 30 inputs, were then cleansed, edited, and coded into CFA format. Reduction of the variables to satisfy the matrix dimension constraint of CFA was the next step. This was accomplished using a combination of 1) replacing subsets by total quantities; 2) combining like data; and 3) statistically reviewing the data using Pearson Correlations. The final data set contained 8 outputs and 12 inputs to be used in seven different combinations.

Of the seven tests run, three tests produced efficiency measures that are valid for Air Force Fire Departments. Information on the efficient units appearing in proper facets and input and output adjustments to increase the efficiency of inefficient units were shown to be of great assistance to the Fire department managers. The other four tests were unsuccessful due to the inablility of the CFA program to manipulate the combinations of variables. The major contributor to the problem was the broad range of values in a particular variable resulting in potential unboundedness in the linear programming solution.

Research Objective 3

Despite the limitations of the current CFA code, this analysis method still produces results that are more meaningful than those from any other method currently available. The products generated by CFA provide efficiency management information for all levels of management in Civil Engineering. However, in order to fully evaluate Fire Department productivity, effectiveness (goal achievement) must be addressed. An integrated automated management information system incorporating not only CFA analysis but also data from other information sources would enable the managers to develop the optimal productivity strategy. This automated system could also include Fire Department efficiency profiles, contingency and wartime planning forecasts, and annual reviews.

Limitations

Use of the CFA code as it presently exists revealed limitations in the application of the code. Many of the problems encountered pertain to the number of variables and to the data set. The biggest problem was the inability of the CFA code to handle more than 20 input/output variables in any single run. Therefore, the original 72 variables had to be reduced.

The problem with the data pertained to the range of values in a particular variable. If the range was too large, the linear programming matrix was unable to produce meaningful results. Despite the scaling routine built into the CFA program, the range present in the empirical data was too great, and had to be manipulated by other means so the data could be used in CFA analysis.

Another problem that was introduced was the limitation of computer time and money to perform more CFA analysis on the data set. Related to this, there is also the problem of having the CFA code on the University of Texas at Austin mainframe computer, which is inaccessable to AFIT students unless TDYs are approved.

The authors were aware of these specific limitations when conducting this research effort. Although these limitations do not negate the results of this study, they should be considered by researchers contemplating follow-on research.

Recommendations

This research has shown that Constrained Facet Analysis can use empirical data collected for Air Force Fire Departments and provide meaningful results that are useful to fire protection managers. However, several issues must be addressed prior to full implementation in the Air Force and are stated here for further research.

1. Validate input and output candidates as available and applicable; then reduce the candidates statistically prior to the use of Constrained Facet Analysis. To obtain full relationships between non-profit organizational units during Constrained Facet Analysis, empirical data that is collected from the field should be complete and accurate. Missing data can cause an important variable to be left out of the variable list; therefore, further research should consider the changes in data collected by the Work Information System (WIMS) and adjust the variables list accordingly. The data should be statistically reviewed not only by the Statistical Package of Social Sciences (SPSS) PEARSON CORRELATION subroutine, but also by SPSS subroutines CONDESCRIPTIVE, FACTOR ANALYSIS, SCATTERGRAM, and other means to successfully reduce the variables and to reduce the range of values in each variable.

2. Identify a more generalized data set. The data set should combine as many variables as possible to directly or indirectly capture all those fire department characteristics

that Fire Chiefs and managers want to analyze to improve their efficiencies. Once the data set is determined, each variable should be analyzed independently by qualified fire protection experts for its usefulness. Constrained Facet Analysis is continually being updated and future redimensioning of the code to handle more than 20 variables at a time will allow such analysis support.

3. Conduct a survey of Fire Chiefs and other fire protection managers to obtain acceptance of managers toward the variables that will be used to measure their efficiency. Additional research using the Fire Department as the decision making unit could verify each variable's contribution to organizational efficiency. Comparisons of several test runs, using different input/output combinations could prove useful in determining a standard set of variables for the fire department.

4. Expand the Constrained Facet Analysis code to produce products which provide the marginal rates of substitution and marginal rates of productivity that will aid the manager in making performance improvements, thus improving organizational efficiencies.

5. Extend Constrained Facet Analysis into other functional areas of Civil Engineering. Current research efforts are being conducted by Fisher (27) to determine the efficient use of available resources in the Operations Branch of a base civil engineering organization, and by

Astin and Ruff (5) to determine the efficiency of an Engineering Design Section at a base civil engineering organization. Further research into other functional areas of civil engineering should be attempted. Once all functional areas have implemented the Constrained Facet Analysis efficiency model, Constrained Facet Analysis could then be used as a model resulting in a single efficiency rating for the whole organization. One could take all civil engineering functional areas' CFA efficiency ratings and use these ratings as inputs for the efficiency model of the civil engineering organization, resulting in a single efficiency measure for the organization.

6. The authors recommend the Air Force continue to investigate the usefulness of Constrained Facet Analysis. This research has shown that Constrained Facet Analysis is a management tool that could be used by Air Force Fire Departments. Furthermore, the CFA code is continually being improved and updated, and Air Force support would accelerate the implementation of the Constrained Facet Analysis model as a management tool for Air Force Civil Engineering organizations.

Appendix A: Fire Department Workshop Participants

AFESMET Representatives:	
1Lt Michael A. Granger	AFESMET/MEMP
TSgt Rod Haizlip	AFESMET/MEME
GS-11 Larry Ingram	AFESMET/MEMP
HQ AFESC Representatives:	
Capt John Bravo	HQ AFESC/DEMG
Capt Fred Walker	HQ AFESC/DEF
MAJCOM Representaives:	
CMSgt Donald G. Waling	HQ USAFE/DEMF
CMSgt Chester E. Weger	HQ AAC/DEMF
SMSgt George F. Hall	HQ PACAF/DEMF
MSgt Larry D. Lewis	3202 CES/DEF (AFSC)
GM-13 Hampton E. Cayson	HQ MAC/DEMF
GM-13 Billy Ferrell	HQ ATC/DEMF
GM-13 Claude L. King	HQ SPACECOM/DEP
GM-13 George Telford	HQ AFSC/DEMF
GS-12 Irvin R. Brown, Jr.	1st Space Support Group/DEF (SPACECOM)
GS-12 James W. Hailey	HQ AFRES/DEMF
GS-12 Benjamin F. Palmerton, III	HQ SAC/DEMF
GS-12 Jack Walcott	HQ AFLC/DEMF
GS-11 John C. Stokes	325 CES/DEF (TAC)

Appendix B: Air Force Fire Department Tasks

OPERATIONS

I. Structural

A. Provide structural suppression capability

1. Command and control at all levels of supervision

a. Deploy equipment and personnel at the scene

b. Request and deploy mutual aid equipment and personnel

2. Respond to structural emergencies

3. Perform recurrent proficiency training

4. Assure availability of portable equipment

5. Conduct operational tests on ladders and other equipment

6. Develop, maintain and execute pre-fire plans

a. Perform on-site familiarization

b. Prepare pre-fire plans

c. Revise pre-fire plans as changes occur in the facilities

d. Use pre-fire plans during emergency responses

e. Conduct exercises of facilities using pre-fire plans

f. Review pre-fire plans for currency

B. Provide wildland fire suppression capability

1. Assess risk: burnable material, terrain, weather

2. Develop operations plans outlining procedures

3. Respond to wildland fires and perform firefighting operations

4. Train augmentees

5. Use specialized equipment/tools

6. Request/deploy support agencies

7. Determine exposures and limit fire areas with fire breaks and natural barriers

8. Determine available water sources, manpower and equipment

9. Command and control--airborne and ground

10. Develop and contract for nonfederal support

11. Perform control burning

12. Determine fire protection requirements for FAM camps and outdoor recreational areas

C. Provide rescue capability

1. Command and control

2. Assess requirements, align priorities (buildings, cave-in, automobiles, aircraft, water, heights)

3. Use specialized equipment

4. Conduct or receive specialized training

5. Respond to structural/rescue emergencies

6. Perform rescue operations

7. Assist medical personnel

D. Provide crash support

1. Respond to in-flight emergencies

2. Respond to aircraft ground emergencies

3. Crossman crash vehicles

4. Provide additional extinguishing agents to crash trucks

5. Augment rescue teams

6. Assist with interior aircraft fire suppression operations

7. Assist reservice of crash trucks

8. Assist in decontamination

9. Neutralize/control/contain fuel spills

10. Protect exposures

E. Conduct fire cause investigation

1. Investigate fire

2. Preserve evidence

3. Determine cause

4. Prepare reports

F. Participate in Base Recovery Plans After Attack (BRATT) exercises

1. Command and control

2. Responds to BRATT exercises as directed

3. Comply with requirements of AFR 93-3

4. Develop fire protection requirements for BRATT

5. Develop unique tactical requirements for fire fighting/rescue in a chemical warfare/UXO environment

6. Develop dispersal plan for personnel and equipment

7. Develop communications systems locations -- hardened/semi-hardened

8. Assist with gross area decontamination

9. Assist in determining mission critical facilities

10. Develop search and rescue procedures with emphasis on self aid and buddy care

11. Prepare for fire fighting and rescue on collapsed or severely damaged facilities

12. Determine method to confine fire areas through demolition or knock down, aircraft removal, cover area

13. Determine feeding/hygiene/sanitation requirements

14. Receive and bed down Prime BEEF teams

15. Employ Prime BEEF teams

16. Determine reserve equipment and personnel requirements (WRM)

17. Host nation wartime support

18. Recognize LIMFACS--resolve if possible

G. Respond to hazardous materials incidents

1. Establish entry control point

2. Cordinate efforts of disaster response force until relieved by on-scene commander

3. Assist in area evacuation/rescue

4. Determine appropriate action according to hazardous material involved

5. Put on specialized fire protection clothing and equipment

6. Determine proper agent and apply, as necessary

7. Assist appropriate base agencies in actions needed to isolate, contain , extinguish, or neutralize involved materials

H. Contingency operations/exercises

1. Provide command and control at all levels

2. Respond to contingency operation/exercise

3. Terrorist threats--overt/covert potential fire areas

4. Implement antihijack procedures

5. Implement bomb threat procedures

6. Implement procedures to deploy vehicles and personnel

7. Natural disasters

I. Perform standby

1. Command and control

2. Bomb threats

3. In-flight emergency

4. Welding jobs--hazardous or unusual

5. Maintenance activities

6. Mutual aid cover-in

7. R & D hazardous materials

8. Cross manning crash equipment

9. Hazardous materials incidents

10. Dispersal points pre-attack

11. Stand-by at vehicle accidents

12. Others

J. Support fire prevention

1. Perform company inspections

2. Conduct demonstrations, parades and station tours

3. Assist in fire evacuation drills

4. Assist in preschool and school age fire prevention programs

5. Pass out fire prevention literature

6. Assist in babysitters' emergency education programs

K. Support aircraft arresting systems operations

1. Assist in removal, reset, and inspection

2. Assist in disengagement operations

3. Receive proficiency training on applicable systems

L. Provide training to ensure capability

1. Command and control

2. Assess and determine needs

3. Conduct proficiency training IAW AFR 92-1

4. Respond to munitions areas each six months

5. Hostile action survival and sustain operations

6. In-depth training on unique facilities/operations

7. Local National training

II. Crash/Rescue

A. Provide aerospace vehicle fire suppression and rescue capability

1. Respond to emergencies

2. Provide command and control

B. Determine vehicle requirements

1. Justify and requisition vehicles

2. Establish and perform vehicle maintenance

C. Implement manning requirements for vehicles and fire alarm center

D. Establish and implement emergency response requirements and procedures

1. Aircraft fires/crashes on base and off base -- consider time and distance factors, where applicable

E. Provide structural support

1. Use of crash vehicles

2. Cross manning for structural trucks and equipment

3. Assist structural force crews

F. Perform standby

1. Perform abnormal maintenance operations

a. Green engine runs

b. Munitions loading/unloading

c. Cutting and welding operations

d. Fuel spills

e. Fueling/defueling

f. Open fuel cell repairs

g. Integrated combat turns

h. Hot-pit refueling

i. Concurrent refueling with passengers on board

j. Others as required by directive

2. Aircraft landings and takeoffs

a. Mass (more than one)

b. Drone

3. Auxiliary field operations

4. Bombing range operations

5. Medical evacuations

6. Arresting barriers

7. Hydrazine/chemical spills/leaks

8. Special weapons, missile propellents, and other high hazard items, whether in storage or in transit

9. Line standby

G. Conduct and receive firefighter training of mission support

1. On the job training

2. Proficiency training

3. Specialized training

H. Use and maintain protective clothing, breathing apparatus, tools, equipment, and fire suppression agents necessary to ensure mission accomplishment

I. Develop and maintain a trained fire suppression and rescue force capable of supporting the mission

J. Support fire prevention

1. Conduct demonstrations, parades and station tours

2. Pass out prevention literature

3. Assist in open-house activities

K. Support aircraft arresting system operations

1. Inspect and operate systems after normal duty hours

L. Respond to hazardous material incident

1. Establish command and control

2. Perform rescue

3. Controls/abates hazard

4. Plot grid location

5. Establish entry control point

6. Coordinate efforts of disaster response force until relieved by on-scene commander

7. Assist in area evacuation/rescue

8. Determine appropriate action according to hazardous materials involved

9. Wear required fire protection clothing and equipment

10. Determine proper agent and apply as necessary

11. Assist appropriate base agencies in actions needed to isolate, contain, extinguish, or neutralize involved materials

12. Wash down fuel spills as necessary

M. Contingency operations/exercises

1. Train, equip and deploy Prime BEEF firefighting and control teams for contingency and exercise scenarios

2. Develop, train and maintain a response capability for contingencies

a. Disaster preparedness

b. Garden plot

c. Antihijacks

d. Environmental spills

e. BRAAT

f. Mobility

g. Others

N. Develop, maintain and execute pre-fire plans

1. Maintain aircraft pre-fire plans at the following locations

a. Fire Chief's vehicle

b. Assistant Fire Chief's vehicle

c. Communication center

d. Training reference library

e. Master technical order file

f. Rescue vehicle

2. Execute/exercise aircraft pre-fire plans, as required to maintain proficiency, at least quarterly

O. Assist with fire investigation and preparation of reports

P. Support BRAAT

1. Provide firefighting and rescue for priority listed facilities, weapons, systems and equipment

2. Assist with priority decontamination for weapon systems, facilities and equipment

TECHNICAL SERVICES

I. Conduct technical reviews and evaluations

- A. Repair, renovation and construction projects (in-house and contract)
  1. Review AF Forms 332
  2. Review AF Forms 1391
  3. Review and assist in preparation of project booklets
  4. Review design analysis
  5. Review project specifications and design drawings
  6. Attend pre-final inspections
  7. Attend final inspections

II. Conduct fire prevention/safety inspections

- A. Obtain and develop inspection folders
- B. Develop inspection schedule
- C. Review inspection documents
- D. Conduct inspections, scheduled and unscheduled
- E. Complete required documentation
- F. Outbrief building/functional managers
- G. Monitor/follow-up corrective actions

III. Monitor Fire Safety Deficiency (FSD) programs

- A. Identify deficiencies
- B. Report deficiencies for correction
- C. Monitor programming action for correction

IV. Develop and conduct educational and training programs

A. Develop training aids and lesson plans, secure promotional materials to support education and training programs

B. Conduct education and training programs

1. Seasonal campaigns
2. Newly assigned people
3. Building/functional managers
4. Commanders/supervisors
5. Dependent schools/child care centers
6. Family housing
7. Special/occupational
8. Fire extinguisher operation and use
9. Facility fire evacuation
10. Fire prevention inspection proficiency
11. Contractors
12. Social groups
13. Mission critical functions
14. Others

V. Provide consultant services

A. Project and design engineers

B. Base safety office

C. Commanders and supervisors

D. Facility boards

E. Safety council

F. Hazard abatement council

G. Environmental protection council

VI. Develop and/or coordinate directives

A. Base fire regulations

B. Fire emergency operating instructions

C. Host tenant agreements

D. Others

VII. Administration of technical services

A. Develop and maintain documentation

1. Fire Safety Deficiencies (FSD)

2. Education and training

3. Inspections

4. Technical reviews and evaluations

B. Maintain publications

C. Maintain technical reference library

MANAGEMENT

I. Attends and actively participates in base boards

- A. Vehicle authorization and utilization board (VAUB)
- B. Facilities board
- C. Safety council
- D. Working groups and panels
- E. Environmental protection working group
- F. Disaster preparedness

II. Prepares, submits and revises budget

III. Directs internal fire department management and support

- A. Establishes and enforces standards of performance
- B. Interviews occupation (job) applicants
- C. Ensures readiness of fire suppression capability
- D. Manages human, physical, real property OSSGTS
- E. Indoctrinates new employees
- F. Responsible for provision of and motivation of health, welfare and environmental conditions
- G. Established local policies/procedures and interfaces with union/military officials
- H. Participates in labor/management contract negotiations
- I. Promotes labor/management relations
  1. Union
  2. Social actions
  3. Equal employment opportunity

4. Other

J. Interprets and implements Air Force, MAJCOM and Wing policies

K. Establishes and implemants a pre-fire planning program

L. Acts as final base fire protection approval authority on O & M, MCP project reviews

M. Conducts supervisory staff meetings

N. Establishes and monitors departmental physical conditioning program and fitness of personnel

O. Attends professional association meetings and coordinates with other agencies to acquire diversified interface on current fire protection initiatives, developments and states of the art

VI. Provide Commanders' guidance on fire protection program

A. Conducts staff meetings

B. Advises commanders on current fire protection problems and provides solutions, alternatives and courses of action

C. Apprises commander of fire incidents, losses, actions, etc.

VII. Directs internal fire department training programs

A. Establishes and implements OJT program

B. Establishes and implements proficiency training program according to mission

C. Establishes and implements readiness training program

D. Monitors overall training programs

E. Encourages and promotes self-improvement via educational programs

F. Conducts supervisory training

G. Acquires facilities, equipment and training aids to accomplish training objectives

VIII. Initiate command and control for base incidents

A. Coordinates, controls and manages fire scene operations

B. Interfaces with support staff agencies

C. Initiates recall and mutual aid responses

D. Implements options

E. Monitors fire scene to ensure safety of personnel and equipment

F. Initiates requests for investigation of suspicious fires, directs post-fire operations to include debriefing of firefighters

IX. Provides administrative capability

A. Prepares, monitors, signs and submits reports

B. Establishes administrative positions, functions and assigns duties

C. Drafts, edits and finalizes correspondence

D. Operates data processing equipment

E. Establishes, monitors and maintains data system

F. Operates (inputs/retrieves data) WIMS

G. Ensures maintenance of records, reports, publications and documentation

F. Types correspondence

X. Coordinates support agreements

A. Determine the amount of support needed for mutual aid

B. Develop interservice support agreements

C. Support status of forces agreement

D. Support alliance agreements

E. Develop memorandum agreements

F. Develop memorandums of understanding

G. Develop host tenant agreements

H. Develop joint-use agreements

I. Other

XI. General management

A. Prepare for strikes that affect host nations, mutual aid and other agreements

B. Assess possible contingency threats

C. In coordination with other agencies, implement plans to cope with all probable contingencies

XII. Self Contained Breathing Apparatus (SCBA) inspection and maintenance

A. Obtain/requisition required SCBA

B. Obtain/requisition required spare cylinders

C. Develop and implement inspection, test and maintenance program

1. Perform operator/user inspections

2. Perform inspections/maintenance

3. Conduct air sample

D. Operate, maintain and reservice equipment

1. Compressor/purifier

2. Cascade

E. Document inspection, test and maintenance records

F. Conduct and receive training for maintenance

XIII. Accomplish fire extinguisher maintenance

A. Determine fire extinguisher requirements

B. Obtain and distribute extinguishers

C. Establish a scheduled inspection, testing and maintenance program

1. Perform scheduled maintenance, inspection and testing IAW NFPA IO, AF TO's and AFOSH standards

2. Provide facility and equipment to perform the maintenance

3. Coordinate bench stock/shop stock to perform maintenance

D. Perform unscheduled repair, reservicing and maintenance

E. Redistribute repaired, reserviced, wheeled extinguishers

F. Support fire prevention training and educational programs

G. Perform operator's care and maintenance of assigned vehicle

H. Maintain assigned facility

XIV. Logistics support (Supply)

A. Identify resource requirements

B. Prepare and process logistic requests

C. Conduct follow-up action on supply documents

D. Review and update CA/CRL

E. Maintain physical inventory

F. Maintain supply discipline

G. Establish and maintain stock levels (bench/shop/special)

H. Maintain reference library

I. Conducts internal training/supply discipline

J. Ensures compliance with Federal specifications

K. Perform data search

L. Evaluate serviceability of protective clothing and support equipment

M. Coordinates repair/maintenance for equipment

N. Assists in preparing budget

O. Picks up, receives receipts, delivers, turns in and issures resources

P. Attends supply custodian courses

Q. Performs supply liaison with applicable agencies

R. Provides essential logistic support functions during emergencies (SCBA, reservicing, clothing, agent, etc.)

S. Assists in preparation of Material Deficiency Reports (MDR's), reports of survey and Quality Deficiency Reports (QDR's) as required

XV. Logistics support (Vehicles)

A. Identify vehicle discrepancies using applicable technical orders and supplemental checklists

B. Reports discrepancies to LGT

C. Maintains awareness of LGT special levels/bench stock/parts requisition

D. Conducts follow-up actions to ensure correct FAD/priority is assigned to requisition

E. Uses and conducts technical order research

F. Coordinates scheduled maintenance

G. Conducts and documents vehicle tests

H. Maintains technical order reference library

I. Ensures vehicle serviceability/reliability

J. Conducts vehicle operations training

K. Attends VAUB meetings

L. Prepares and submits AF Forms 1374 and 601

XVI. Alarm communications operations

A. Establish a primary/alternate fire alarm communications center

1. Staff with qualified operators to perform a 24 hour service

2. Operate alarm receiving and recording equipment, data storage and retrieval system, computer aided dispatch system, communications equipment, etc.

B. Use written operating instructions/procedures for alarm receipt, dispatch and notification of support agencies, operation of alarm equipment, standby requirements, etc.

C. Use and maintain maps, charts, graphs, logs and reference library

D. Research data and relay information to senior fire official

E. Receive incoming communications and relay to appropriate authority; notify, dispatch and coordinate emergency, exercise, contingency responses

F. Conduct and/or receive training

G. Provide information for the consolidation and preparation of records and reports

H. Perform housekeeping tasks

I. Perform BCE service call function after duty hours

TABLE C.1

Fire Department Input Candidates

Category	Candidate	Justification	Source
Personnel Cost	Civilian Pay Military Pay	Useful in reallocations of inputs since the Department of Defense ultimately considers evaluation in dollars	RC Managers Report
	Total and Total Available Fire Dept Manhours	Total vs Total Available evaluates the effect of leave and loaned labor	BEAMS Retrieval
	- Operations - Technical Services	Dividing labor into classes for identification of specific functional effects	BEAMS Retrieval
	OR		
	- Civilian - Military	Civilian - Military for evaluation of mix impact and for evaluating Prime BEEF impact	BEAMS Retrieval

TABLE C.1 Continued

Category	Candidate	Justification	Source
	OR - Skill Levels 57100 57190 57170 57150 57130 - 57110	Skill levels are surrogates for job training and competency, and would be useful in detecting imbalances among units	BEAMS Retrieval
	Total number of Technical Service Inspectors	Used to evaluate the use of personnel and in conjunction with number of inspections	Technical Services Chief
Cost of Equipment, Supplies, and Vehicles	Annual Supply Expenditure Annual Equipment Expenditure (excluding vehicles)	Useful in budget considerations for dollar input adjustments	RC Managers Report
	Number of Vehicles - Total - Crash/Firefighting - Structural - Other	Evaluates impact of vehicle mix and number for base mission and size	VIMS

TABLE C.1 Continued

Category	Candidate	Justification	Source
	Value of Vehicles - Total - Crash/Firefighting - Structural - Other	Surrogate for vehicle age and condition. Useful in itself and for replacement consideration	VIMS
	Vehicle Available Hours	Useful for itself and as a surrogate for maintenance support	VIMS
	Equipment Value (excluding vehicles)	Surrogate for equipment condition and indicator of equipment support	CA/CRL
Capitalized Cost of Fire Protection Utilized Real Property (acquisition value)	Value of Fire Dept Facilities	Surrogate for evaluating the impact of physical well-being on outputs	BEAMS Real Property Records
Cost of Utilities	None included	May be a factor of Fire Dept efficiency. Responsibility resides with Civil Engineering in general. Data is not readily available since individual building utilities are not metered.	

TABLE C.1 Continued

Category	Candidate	Justification	Source
Maintenance Costs on Real Property	None included	May be a factor of Fire Dept efficiency. Responsibility resides with Civil Engineering Operations Branch, and could possibly be a surrogate for management measurement. Not included since data is not currently available.	
None	Contracted Services Expenditure	Included as a surrogate for manhours expended for services provided by contractors instead of in-service	RC Managers Report

TABLE C.2

Fire Department Technical Services Branch Output Candidates

Category	Candidate	Justification	Source
Conducts Technical Reviews and Evaluations AND	Total Documents Reviewed (number) - In-Service Work - Contract Work	Supports the Engineering and Operations Branches in insuring that fire codes are met. The subsets are for managerial use in evaluation of support.	Technical Services Chief
Monitors Fire Safety Deficiency (FSD) Programs	Total Documents Reviewed (manhours) - In-Service Work - Contract Work	Same as above	Technical Services Chief
Conduct Fire Prevention Inspections	Total number of Inspections - Housing - Other	Useful in direct measurement as well as a ratio of inspections per inspector	AF Form 1528
Develop and Conduct Training Programs AND Develop and Conduct Education Program	Total number of Presentations - On-base - Off-base	Direct measurement and guide to management on where emphasis is or should be placed	AF Form 1528

TABLE C.2 Continued

Category	Candidate	Justification	Source
Provide Technical Advice to Facilities Board and Pre-Design Board	Not Measured	Excluded since there are currently no quantifiable measures of any of the following seven categories, either in manhours or in incidents. Assumption must be made that support in these areas is adequate or equal for all units measured	
Develop, Review, and Coordinate Fire Prevention Regulations and Publications	Not Measured		
Provide Consultant Services	Not Measured		
Fire Extinguisher Maintenance	Not Measured		
Logistic Support	Not Measured		
Self Contained Breathing Apparatus (SCBA) Maintenance	Not Measured		
Administration of Technical Services	Not Measured		

TABLE C.3

Fire Department Operations Branch Output Candidates

Category	Candidate	Justification	Source
STRUCTURAL			
Provide Structural Suppression Capability AND	Number of Building Fire Responses - Housing - Other	Mission responsibility. The subsets help management in determining how well the priority of fires is applied	AF Form 1528
Provide Wild Land Fire Suppression Capability	Manhours Spent in Building Fire Responses - Housing - Other	Mission responsibility	AF Form 1528
	Mutual Aid Responses - Number - Manhours	Assists managers in determining whether the base mission is being compromised by serving others	AF Form 1528
	Building Fire Loss ($) (reciprocal value) - Housing - Other	Indicates how effective the Fire Dept is once they have responded to a fire	AF Form 1528

TABLE C.3 Continued

Category	Candidate	Justification	Source
Provide Structural Suppression Capability	Loss per Reportable Fire (reciprocal value) - Housing - Other	Alternative to above measure	AF Form 1528
	Effective Base Population	Evaluates personnel subject to protection	Public Affairs
	Number of Fire Stations	Evaluates response time when considered in conjunction with Land Area (surrogate measure)	Real Property Records
	Land Area	Surrogate for response time when taken in consideration with Fire Stations	Real Property Records
	Number of Housing Units	Surrogate for population of base housing subject to protection	Real Property Records
	Real Property Value at Risk (excluding aircraft) - Housing Value - Industrial Structure Value	Identifies real property subject to protection. Aids in determining similar units.	Real Property Records

TABLE C.3 Continued

Category	Candidate	Justification	Source
Provide Rescue Capability	Fire-Related Injuries (reciprocal value) - Firefighters - Base Populace	Surrogate measurement for ability to save lives and prevent injuries	AF Form 278
	Fire-Related Deaths (reciprocal value) - Firefighters - Base Populace	Surrogate measurement for ability to save lives and prevent injuries	AF Form 278
CRASH/RESCUE			
Provide Aerospace Vehicle Suppression Capability	Aerospace Vehicle Responses - Number - Manhours	Mission requirement	AF Form 1528
	Aircraft Incidents	Mission requirement	AF Form 278
	Fuel Spill Responses - Number - Manhours	Mission requirement	AF Form 1528

TABLE C.3 Continued

Category	Candidates	Justification	Source
Provide Aerospace Vehicle Suppression Capability	Aircraft Standbys - Number - Manhours	Mission requirement	AF Form 1528
	Other Standbys - Number - Manhours	Mission requirement	AF Form 1528
	Aircraft Value at Risk	Identifies aircraft subject to protection	AF Form 278
	Aircraft Loss ($)	Indicates how effective suppression effort is	AF Form 278
	Number of Landings and Takeoffs	Evaluates opportunity for aircraft response	Air Traffic Control
	Number of Active Runways	Possible surrogate for opportunity for aircraft responses	Real Property Records

TABLE C.3 Continued

Category	Candidate	Justification	Source
Provide Aerospace Vehicle Rescue Capability	Fire-Related Injuries (reciprocal values) - Firefighters - Base Populace	Surrogate measurement for ability to save lives and prevent injuries. Rescue is included in all operational requirements and is not measured separately. No separate figures are available for Crash/Rescue and Structural.	AF Form 278
	Fire-Related Deaths (reciprocal values) - Firefighters - Base Populace	Same as above	AF Form 278
Provide Training to Insure Capability	Classroom Training - Number of Sessions - Manhours	Direct measurement. On-the-job training is included in the response	AF Form 1528
GENERAL			
Respond to Hazardous Material Incident	Other Responses - Number - Manhours	This measure includes other responses in addition to the hazardous materials, e.g. bomb threats, false alarms	AF Form 1528

TABLE C.3 Continued

Category	Candidate	Justification	Source
Support Base Recovery After Attack Team (BRAAT)	Prime BEEF Training - Number of Incidents - Manhours	Support of the contingency mission is inherent in the Fire Dept's share in Civil Engineering	BEAMS - Labor Reporting Retrieval
AND			
Contingency Operations and Exercises			
Inspect, Test, and Maintain Equipment and Facilities	Not Measured	Not currently measureable in quantifiable terms. Must assume all units are equal	

NOTE: Due to the cross-manning policies of the Air Force Fire Departments, the Operations Section of the Fire Department, though divided into Crash/Rescue and Structural missions, utilizes all firefighters in both missions, Operations also assists Technical Services when peak workload requires it. The cross-manning policy is based on the premise that there will never be an instance where a Crash/Rescue and Structural requirement occur simultaneously, not in the same location.

TABLE C.4

Fire Department Management Branch Output Candidates

Category	Candidate	Justification	Source
Develop, Maintain, and Execute Pre-Fire Plans	Not Measured	All Management categories are not individually quantifiable. A process measure (manhours in cost center 425, Fire Department Management) will be used.	RC Manager's Report
Alarm/Communication Operations	Not Measured		
Provide Wing Commander Guidance on Fire Protection Program	Not Measured		
Command and Control for Base Incidents	Not Measured		
Internal Fire Dept Management, Support and Training	Not Measured		

Appendix D: A Single Output, Two Input Example of Constrained Facet Analysis

Written by: Lt Col Terry C. Clark and Lt Timothy A. Byers

The capabilities and properties of Constrained Facet Analysis (CFA) now will be demonstated by performing a CFA evaluation of four single output, two input data points. Suppose organizational units A, B, C and D shown in Table D.1 each produced the same two types of resources, X_1 and X_2, during some specified time period. Table D.1 provides the amounts of outputs produced and inputs consumed by units A through D during the production process.

TABLE D.1

Input and Output Values for Organization A through D

Organizational Units	Inputs X_1	Inputs X_2	Output Y
A	5	7	1
B	4	4	1
C	5	2	1
D	6	4	1

Figure D.1 is the geometric representation of the data in Table D.1. Because each unit produces the same amount of output, Y = 1, the linear frontier segment in Figure D.1 connecting units B and C is efficient relative to the remaining units A and D regardless of the relative

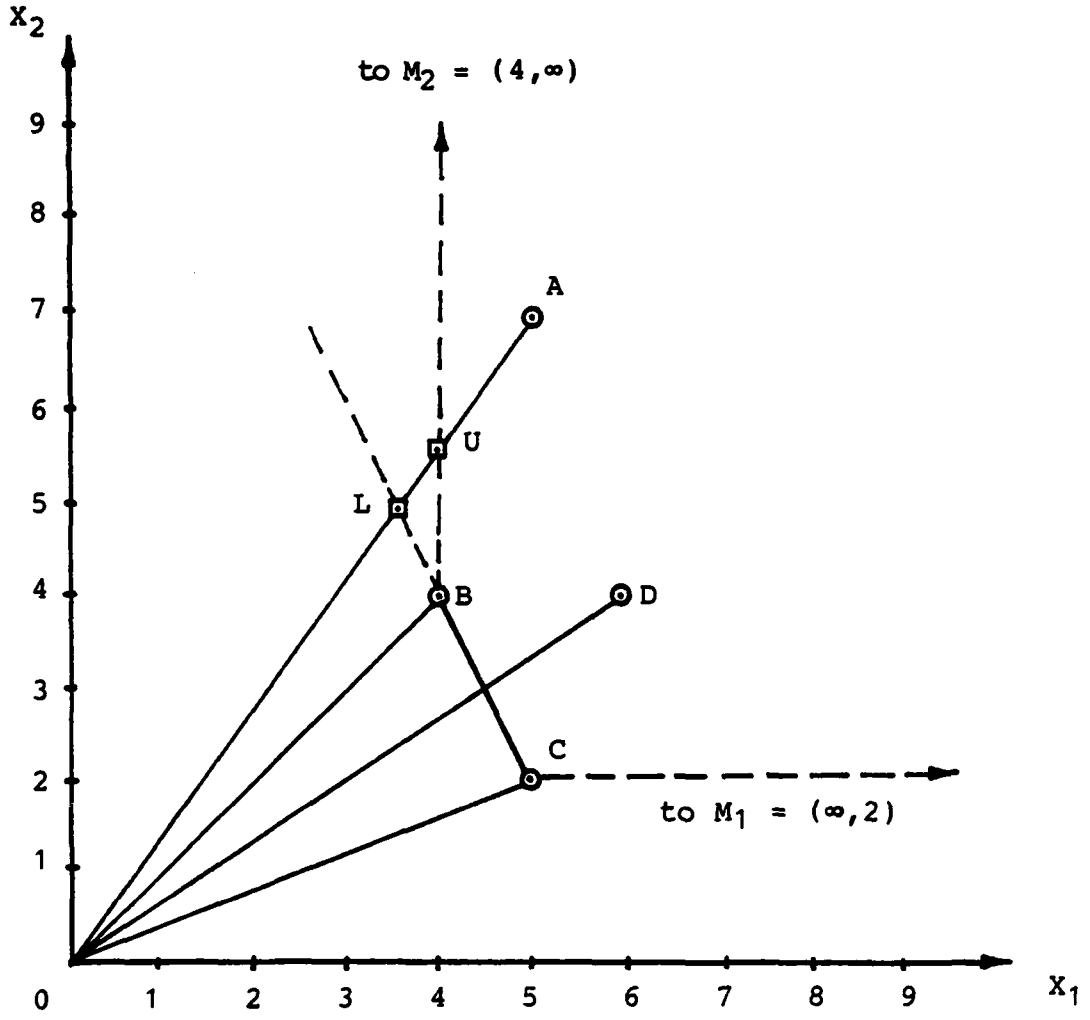

Figure D.1 Plot of a Single Output (Y = 1) and Two Input Case for Units A through D

"weights" or "costs" of inputs X_1 and X_2. In fact, if p_1 is the cost of X_1 and if p_2 is the cost of X_2, then C is preferred to or more efficient than A, B and D when $p_1 \geq 2p_2$; B is preferred when $1/2p_2 \leq p_1 \leq 2p_2$; and C, when $p_1 \leq 1/2p_2$.

Because the ray from the origin to point D (Figure D.1) crosses the linear frontier segment $\overline{BC}$, this unit is "fully enveloped" by the frontier, and only one iteration of CFA is required to evaluate it. Unit A, on the other hand, is an "outlier" in the sense that ray $\overline{OA}$ does not cross frontier segment $\overline{BC}$.

One might believe that full envelopment is a common occurance even in multiple input, multiple output situations. In actual practice, full envelopment rarely occurs in multiple input/output analyses. In all field implementations or demonstations of CFA known to the authors, a lack of full envelopment is the rule rather than the exception. In fact, during an evaluation of Texas schools in 1983, about 60% of the schools evaluated were inefficient (over 300 inefficient ratings), and all of these inefficient schools were not fully enveloped (20).

Constrained Facet Analysis was developed to handle the numerous situations in which units are not fully enveloped. Therefore, the discussion that follows will focus primarily on the CFA evaluation of unit A which is the only not fully enveloped unit in this example.

Constrained Facet Analysis of Unit A

The primal model of CFA for unit A at iteration one is:

PRIMAL

Maximize: $f_A^{(1)} = \mu_A^{(1)} + 5\nu_{1A}^{(1)} + 7\nu_{2A}^{(1)}$ (1)

Subject to:

$$\mu_A^{(1)} - 5\nu_{1A}^{(1)} - 7\nu_{2A}^{(1)} < 0$$

$$\mu_A^{(1)} - 4\nu_{1A}^{(1)} - 4\nu_{2A}^{(1)} < 0$$

$$\mu_A^{(1)} - 5\nu_{1A}^{(1)} - 2\nu_{2A}^{(1)} < 0$$

$$\mu_A^{(1)} - 6\nu_{1A}^{(1)} - 4\nu_{2A}^{(1)} < 0$$

$$5\nu_{1A}^{(1)} + 7\nu_{2A}^{(1)} < 1$$

$$\mu_A^{(1)} > 0 \quad \nu_{1A}^{(1)} > 0 \quad \nu_{2A}^{(1)} > 0$$

The dual formulation of this model is:

DUAL

Minimize: $g_A^{(1)}$ (2)

Subject to:

$$\delta_A^{(1)} + \delta_B^{(1)} + \delta_C^{(1)} + \delta_D^{(1)} - s_A^{(1)} = 1$$

$$5g_A^{(1)} - 5\delta_A^{(1)} - 4\delta_B^{(1)} - 5\delta_C^{(1)} - \delta_D^{(1)} - s_{1A}^{(1)} = 5$$

$$7g_A^{(1)} - 7\delta_A^{(1)} - 4\delta_B^{(1)} - 2\delta_C^{(1)} - \delta_D^{(1)} - s_{2A}^{(1)} = 7$$

$$\delta_A^{(1)}, \delta_B^{(1)}, \delta_C^{(1)}, \delta_D^{(1)} > 0$$

$$s_A^{(1)}, s_{1A}^{(1)}, s_{2A}^{(1)} > 0$$

$g_A^{(1)}$ unrestricted in sign

The optimal solutions of models (1) and (2) yield:

$\mu_A^{(1)*} = 4/5$ $\quad \nu_{1A}^{(1)*} = 1/5$ $\quad \nu_{2A}^{(1)*} = 0$

$f_A^{(1)*} = g_A^{(1)*} = 4/5 + 1 = 9/5$

$\delta_A^{(1)*} = 0$ $\quad \delta_A^{(1)*} = 1$ $\quad \delta_C^{(1)*} = 0$ $\quad \delta_D^{(1)*} = 0$

$s_A^{(1)*} = 0$ $\quad s_{1A}^{(1)*} = 0$ $\quad s_{2A}^{(1)*} = 8/5$

The upper bound efficiency measure is $h_A^{U*} = g_A^{(1)*} - 1 = \mu_A^{(1)*} = 4/5$. To achieve this high rating, the model compared unit A to unit B only ($\delta_B^{(1)*} = 1$) and input X_2 was ignored or given zero value in the analysis ($\nu_{2A}^{(1)*} = 0$ and $S_{2A}^{(1)*} = 8/5$). Because $S_{2A}^{(1)*} = 8/5$, a second iteration of CFA is required to bring another vector of inputs on the frontier into the basis to replace the slack vector. The primal and dual formulations of the second iteration are:

PRIMAL

$$\text{Maximize:} \quad f_A^{(2)} = (8/5)S_{2A}^{(1)*}\nu_{2A}^{(2)} = (8/5)\nu_{2A}^{(2)} \tag{3}$$

$$\text{Subject to:} \quad \mu_A^{(2)} - 5\nu_{1A}^{(2)} - 7\nu_{2A}^{(2)} \leq 0$$

$$\mu_A^{(2)} - 4\nu_{1A}^{(2)} - 4\nu_{2A}^{(2)} = 0$$

$$\mu_A^{(2)} - 5\nu_{1A}^{(2)} - 2\nu_{2A}^{(2)} \leq 0$$

$$\mu_A^{(2)} - 6\nu_{1A}^{(2)} - 4\nu_{2A}^{(2)} \leq 0$$

$$5\nu_{1A}^{(2)} + 7\nu_{2A}^{(2)} = 1$$

DUAL

$$\text{Minimize:} \quad g_A^{(2)} \tag{4}$$

$$\text{Subject to:} \quad \delta_A^{(2)} + \lambda_B^{(2)} + \delta_C^{(2)} + \delta_D^{(2)} - S_A^{(2)} = 0$$

$$5g_A^{(2)} - 5\delta_A^{(2)} - 4\lambda_B^{(2)} - 5\delta_C^{(2)} - 6\delta_D^{(2)} - S_{1A}^{(2)} = 0$$

$$7g_A^{(2)} - 7\delta_A^{(2)} - 4\lambda_B^{(2)} - 2\delta_C^{(2)} - 4\delta_D^{(2)} - S_{2A}^{(2)} = 8/5$$

$$\delta_A^{(2)},\ \delta_C^{(2)},\ \delta_D^{(2)} \geq 0$$

$$S_A^{(2)},\ S_{1A}^{(2)},\ S_{2A}^{(2)} \geq 0$$

$$g_A^{(2)},\ \lambda_B^{(2)} \text{ unrestricted in sign}$$

The optimal solutions of (3) and (4) yield:

$$f_A^{(2)*} = s_{2A}^{(1)*}\nu_{2A}^{(2)*} = g_A^{(2)*} = 8/85$$

$$\mu_A^{(2)*} = 12/17 \qquad \nu_{1A}^{(2)*} = 2/17 \qquad \nu_{2A}^{(2)*} = 1/17$$

$$\delta_C^{(2)*} = -8/17 \qquad \delta_A^{(2)*} = \delta_D^{(2)*} = 0 \qquad \lambda_B^{(2)*} = -8/17$$

$$s_A^{(2)*} = s_{1A}^{(2)*} = s_{2A}^{(2)*} = 0$$

The lower bound efficiency measure is $h_A^{L*} = \mu_A^{(2)*} = 12/17$. Note also that $h_A^{U*} - h_A^{L*} = \mu_A^{(1)*} - \mu_A^{(2)*} = 4/5 - 12/17 = 8/85 = f_A^{(2)*} = g_A^{(2)*}$. Thus, the optimal value of the objective function for iteration two, $f_A^{(2)*}$, is the amount of decrease in the efficiency rating which occurs when unit A's efficiency is measured relative to unit B and C instead of unit B alone. This can be shown mathematically as follows.

Let L and U be vectors from the origin O to points L and U in Figure D.1. The upper bound efficiency measure, h_A^{U*}, is the length of the vector $\overline{U}$ divided by the length of vector $\overline{A}$; or, in other words:

$$h_A^{U*} = \frac{\overline{OU}}{\overline{OA}} = \mu_A^{(1)*}$$

Similarily,

$$h_A^{L*} = \frac{\overline{OL}}{\overline{OA}} = \mu_A^{(2)*}$$

Furthermore, the following equality holds optimality of iteration one:

$$s_A^{(1)*} = \begin{pmatrix} s_{1A}^{(1)*} \\ s_{2A}^{(1)*} \end{pmatrix} = (g_A^{(1)*} - 1)\overline{A} - \delta_B^{(1)*}\overline{B}$$

$$= \mu_A^{(1)*}\overline{A} - \delta_B^{(1)*}\overline{B} \qquad (5)$$

And, from the dual of iteration two:

$$\bar{s}_A^{(1)*} = g_A^{(2)*}\bar{A} - \delta_C^{(2)*}\bar{C} - \lambda_B^{(2)*}\bar{B} \qquad (6)$$

Together, (5) and (6) imply

$$\mu_A^{(1)*}A - \delta_B^{(1)*}\bar{B} = g_A^{(2)*}\bar{A} - \delta_C^{(2)*}\bar{C} - \lambda_B^{(2)*}\bar{B} \qquad (7)$$

Collecting like terms in (7), one obtains:

$$\begin{aligned}\mu_A^{(1)*}\bar{A} - g_A^{(2)*}\bar{A} &= \delta_C^{(2)*}\bar{C} + \delta_B^{(1)*}\bar{B} - \lambda_B^{(2)*}\bar{B} \\ &= (0 - \delta_C^{(2)*})\bar{C} + (\delta_B^{(1)*} - \lambda_B^{(2)*})\bar{B} \\ &= (\delta_C^{(1)*} - \delta_C^{(2)*})\bar{C} + (\delta_B^{(1)*} - \lambda_B^{(2)*})\bar{B} \qquad (8)\end{aligned}$$

The optimal dual solutions of iterations one and two also yield:

$$\begin{aligned}&(0 - \delta_C^{(2)*}) + (\delta_B^{(1)*} - \lambda_B^{(2)*}) \\ &= (0 - 8/17) + [(1 - (-8/17)] \\ &= 1 + 8/17 - 8/17 = 1. \qquad (9)\end{aligned}$$

Equality (8) shows that the vector $\mu_A^{(1)*}\bar{A} - g_A^{(2)*}\bar{A}$ is a linear combination of vectors $\bar{B}$ and $\bar{C}$. According to equality (9), this vector, which extends from the origin along A, terminates at a point on the line passing through both points B and C. Thus,

$$\mu_A^{(1)*}\bar{A} - g_A^{(2)*}\bar{A} = \bar{L}. \qquad (10)$$

By definition,

$$\bar{U} = \mu_A^{(1)*}\bar{A} = h_A^{U*}\bar{A}, \tag{11}$$

and

$$\bar{L} = \mu_A^{(2)*}\bar{A} = h_A^{L*}\bar{A}. \tag{12}$$

Combining (10), (11) and (12) yields:

$$\bar{U} - \bar{L} = (h_A^{U*} - h_A^{L*})\bar{A} = g_A^{(2)*}\bar{A}.$$

Hence,

$$\mu_A^{(1)*} - \mu_A^{(2)*} = h_A^{U*} - h_A^{L*} = g_A^{(2)*}; \text{ or,}$$

in other words, the decrease in efficiency, $h_A^{U*} - h_A^{L*}$, equals the value of the objective function, $g_A^{(2)*}$, at optimality of the second iteration.

Figure D.2 and D.3 provide a geometric interpretation of this proof. In Figure D.2, the vector $\bar{L}$ is shown as a linear combination of vectors $\bar{B}$ and $\bar{C}$. Figure D.3 demonstrates how the surplus vector $(0, S_{2A}^{(1)*})^T$ has been replaced in the second iteration of CFA by the vectors $(h_A^{U*} - h_A^{L*})\bar{A}$ and $-\delta_C^{(2)*}\bar{C} - \lambda_B^{(2)*}\bar{B}$.

Upper and Lower Bound Efficiency Measures

The upper and lower bound efficiency measures for each unit A, B, C and D are shown in Table D.2. Since units B and C are on the frontier and since unit D is a fully enveloped inefficient unit, the upper and lower bound efficiency measures for these units are the same. The not fully enveloped unit A was the only unit which required a

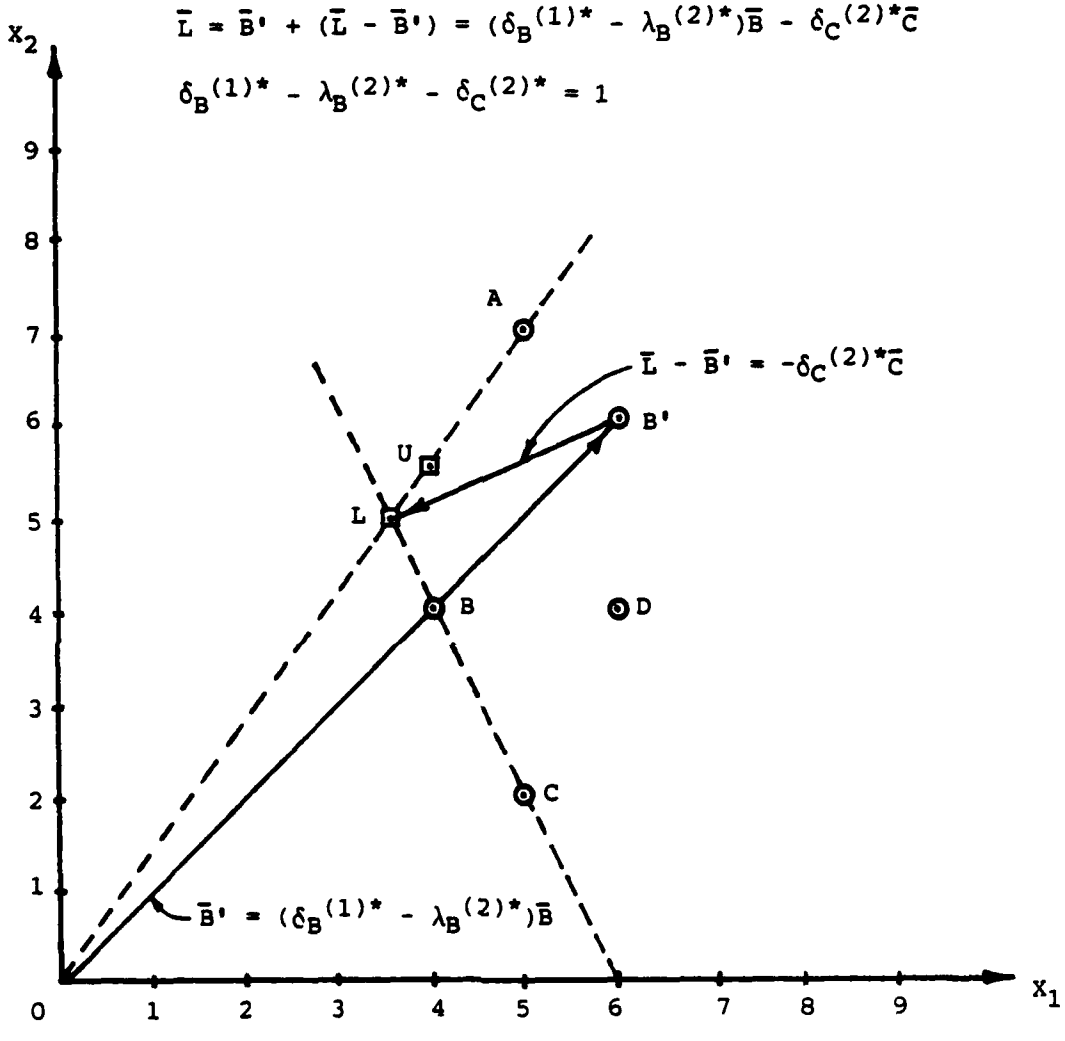

Figure D.2 Vector $\bar{L}$ Shown as a Linear Combination of $\bar{B}$ and $\bar{C}$

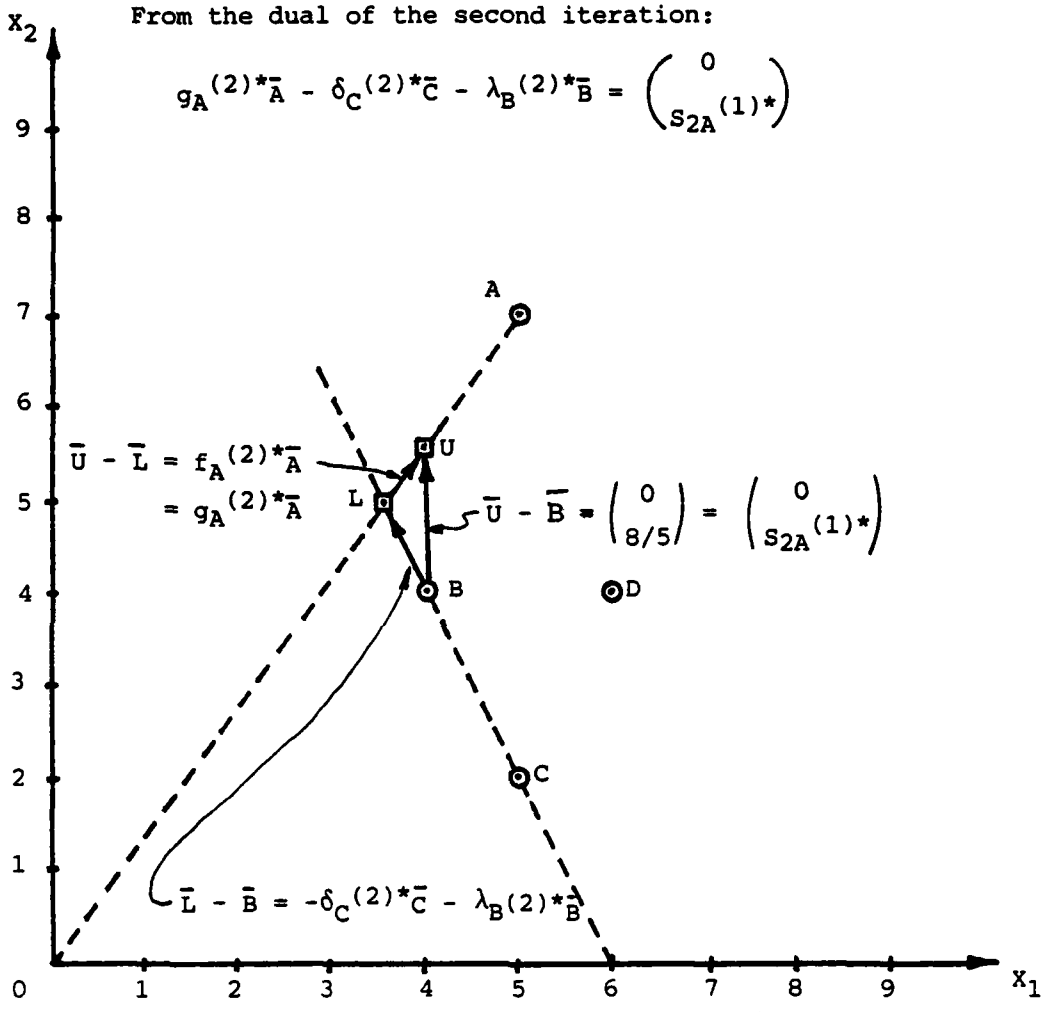

Figure D.3 Replacing the Surplus Vector $\bar{U} - \bar{B}$ with $\bar{L} - \bar{B}$ plus $\bar{U} - \bar{L}$

second iteration and therefore received a reduction in its efficiency rating.

TABLE D.2

Upper and Lower Bound Efficiency Measures for Units A through D

Organizational Unit's	Efficiency Measures	
	Upper Bound (h_j^{U*})	Lower Bound (h_j^{L*})
A	.8000	.7059
B	1.0000	1.0000
C	1.0000	1.0000
D	.7500	.7500

Frontier Facets

Table D.3 displays the frontier facets used as criteria for measuring the relative efficiency of each of the units. Also provided are the associated multipliers for each iteration and any alternative optima. Note that sets of nonzero multipliers were obtained from iteration one for all units except A. Unit A had one zero multiplier, $v_{2j}^{(1)*} = 0$, and one surplus value, $S_{2A}^{(1)*} = 8/5$, at optimality of the first iteration. During iteration two, the frontier reference for evaluation of A changed from the "artificial" facet $\overline{3M}_2$ to the proper facet $\overline{BC}$, and nonzero multipliers were generated as a result of this change.

The efficiency measures and multipliers provided by CFA for unit D can be used to evaluate the marginal rates of

TABLE D.3

Frontier Facets for Units A through D and Associated Values of Multipliers

Organizational Units j = A,B,C,D	Frontier Segments (or Facets) First Iteration	Frontier Segments (or Facets) Last Iteration[1]	Asssociated Multipliers $(\mu_j^{(1)*}, \nu_{1j}^{(1)*}, \nu_{2j}^{(1)*})$	Asssociated Multipliers $(\mu_j^{(2)*}, \nu_{1j}^{(2)*}, \nu_{2j}^{(2)*})$	Alternate Optima
A	$\overline{BM}_2$ where $M_2 = (4,\infty)$	$\overline{BC}$	(4/5,1/5,0)	(12/17,2/17,1/17)	
B	$\overline{BC}$ or		(1,1/6,1/12)		$\alpha(1,1/6,1/12) + (1-\alpha)(1,1/4,0)$, $0 \leq \alpha \leq 1$
	$\overline{BM}_2$		(1,1/4,0)		
C	$\overline{BC}$ or		(1,1/6,1/12)		$\alpha(1,1/6,1/12) + (1-\alpha)(1,0,1/2)$, $0 \leq \alpha \leq 1$
	$\overline{CM}_1$ where $M_1 = (\infty,2)$		(1,0,1/2)		
D	$\overline{BC}$		(3/4,1/8,1/16)		

[1] The first iteration was the last for units B, C, and D.

substitution and marginal rates of productivity in the frontier facet $\overline{BC}$.

Marginal Rates of Substitution and Productivity

According to Clark (20), the marginal rates of substitution between inputs X_1 and X_2 in $\overline{BC}$ can be computed as follows:

$$\left(\frac{\partial X_2}{\partial X_1}\right)_{\overline{BC}} = -\frac{\nu_{1D}^{(1)*}}{\nu_{2D}^{(1)*}} = -\frac{1/8}{1/16} = -2$$

The marginal rates of productivity associated with this facet can also be obtained as follows:

$$\left(\frac{\partial Y}{\partial X_1}\right)_{\overline{BC}} = \frac{\nu_{1D}^{(1)*}}{\mu_D^{(1)*}} = \frac{1/8}{3/4} = 1/6,$$

and

$$\left(\frac{\partial Y}{\partial X2}\right)_{\overline{BC}} = \frac{\nu_{2D}^{(1)*}}{\mu_D^{(1)*}} = \frac{1/6}{3/4} = 1/12.$$

These rates of substitution and productivity can be used to investigate alternative efficient combinations of outputs and inputs which might improve productivity.

Values if Efficient

Managers of inefficient units would like to know which changes in inputs or outputs would lead to an efficient rating. There are an infinite number of alternative

input/output combinations which an inefficient unit could adopt to achieve the frontier of relative efficiency. These alternatives can be obtained from the optimal solutions of constrained facet analysis. Four alternative projections of values if efficient are given below for unit A.

One way for A to achieve an efficient rating would be to reduce its input vector by multiplying it by the upper bound efficiency, $h_A^{U*} = 4/5$, and then subtracting the surplus vector, $\bar{S}_A^{(1)}$, which would yield:

$$h_A^{U*}\bar{A} - \begin{pmatrix} 0 \\ S_{2A}^{(1)*} \end{pmatrix} = 4/5\begin{pmatrix} 5 \\ 7 \end{pmatrix} - \begin{pmatrix} 0 \\ 8/5 \end{pmatrix} = \begin{pmatrix} 4 \\ 4 \end{pmatrix} = \bar{B}.$$

In other words, A could achieve an efficient rating by lowering its inputs to the levels of B while maintaining its output at the same level $Y_A = 1$.

Or, unit D might wish to adjust its output upward to a value of $(1/h_A^{U*}) = 5/4$ and adjust its inputs as follows:

$$\bar{A} - \begin{pmatrix} 0 \\ \dfrac{S_{2A}^{(1)*}}{h_A^{U*}} \end{pmatrix} = \begin{pmatrix} 5 \\ 7 \end{pmatrix} - \begin{pmatrix} 0 \\ 2 \end{pmatrix} = \begin{pmatrix} 5 \\ 5 \end{pmatrix}.$$

Other alternative values if efficient can be obtained from the second (final) iteration of CFA. Unit A would be rated efficient relative to facet $\overline{BC}$ if $Y_A = 1$ and if the input amounts X_{1A} and X_{2A} could be reduced to:

$$h_A^{L*}\begin{pmatrix} X_{1A} \\ X_{2A} \end{pmatrix} = 12/17\begin{pmatrix} 5 \\ 7 \end{pmatrix} = \begin{pmatrix} 60/17 \\ 84/17 \end{pmatrix}.$$

An efficient rating could also be achieved if the inputs X_{1A} and X_{2A} were held constant, and if the output could be changed to:

$$\left(\frac{1}{h_A^{L*}}\right) Y_A = \left(\frac{1}{12/17}\right) (1) = 17/12.$$

Table D.4 shows the alternatives discussed above plus one other which demonstrates the fact that there are an infinite number of other possibilities. Alternative five in Table D.4 was obtained by using the lower bound efficiency measure and the marginal rate of substitution between inputs X_1 and X_2 in the proper facet $\overline{BC}$ which is nearest to A. For this alternative, the adjusted value of input one, X'_{1A}, is allowed to vary in the range:

$$(X_{2C})(1/h_A^{L*}) = 34/12 \leq X'_{2A} \leq 7 = X_{2A}$$

where (X_{2C}/h_A^{L*}) is the smallest value X'_{2A} can assume and retain $\overline{BC}$ as its reference given that X'_{1A} is forced to trade-off with X'_{2A} according to the following:

$$X'_{1A} = X_{1A} + \left(\frac{\partial x_1}{\partial x_2}\right)_{\overline{BC}} (X'_{2A} - 7)$$

$$= X_{1A} = \left(\frac{-\nu_{2A}^{(2)*}}{\nu_{1A}^{(2)*}}\right) (X'_{2A} - 7)$$

$$= X_{1A} - 1/2(X'_{2A} - 7)$$

$$= 5 - 1/2(X'_{2A} - 7).$$

TABLE D.4

Alternative Values if Efficient for Unit A

	Unit A Observed Values	Alternative Values if Efficient for Unit A				
		(1)	(2)	(3)	(4)	(5)
Output Y	1	1	5/4	1	17/12	17/12
Input X_1	5	4	5	60/17	5	$X'_{1A} = 5 - 1/2(X'_{2A} - 7)$
Input X_2	7	4	5	84/17	7	$34/12 \leq X'_{2A} \leq 7$

Appendix E: Model Used in Constrained Facet Analysis of Not Fully Enveloped Units

The model used in the iterative method called constrained facet analysis is presented in this appendix, a model which can be used in evaluating the range of inefficiency in organizational units and in determining marginal rates of substitution and productivity in frontier facets.

Suppose one wishes to evaluate the relative efficiency of n decision making units (DMUs), each of which uses varying amounts of m inputs and produces varying amounts of s outputs. Using notation conventions similar to those used by Clark (20) let:

x_{ij} = the amount of input type i used by DMU j during the period of observation, i = 1, 2,...,m and j = 1, 2,...,n.

y_{rj} = the amount of output type r produced by DMU j during the period of observation, r = 1, 2,...,s and j = 1, 2,...,n.

x_{ik} = the amount of input type i used by the unit k where k j = 1, 2,...,k,...,n and unit k is the DMU being evaluated. Each DMU in turn will be evaluated.

y_{rk} = the amount of output type r used by DMU_k.

N = 1, 2, 3,...,M is the sequence of iterations of the constrained facet analysis model which ends at iteration M.

$h_k^{(1)}$ = the upper bound efficiency value sought for DMU_k which is determined from the solution of the first iteration of the constrained facet analysis.[1]

$h_k^{(M)}$ = the lower bound efficiency value sought for DMU_k which is determined from the solution of the final iteration (M) of the constrained facet analysis.

$v_{ik}^{(N)}$ = the multipliers for each <u>input</u> type i which will be determined by solution of the Nth iterative model.

$\mu_{rk}^{(N)}$ = the multipliers for each <u>output</u> type r which will be determined by solution of the Nth iterative model.

$s_{rk}^{(N-1)*}$ = the dual surplus values associated with outputs r = 1, 2,...,s of DMU_k at optimality of the previous iteration. For the initial iteration, these surplus values are $s_{rk}^{(N-1)*} = s_{rk}^{(0)*} = y_{rk}$.

$s_{ik}^{(N-1)*}$ = the dual surplus values associated with inputs i = 1, 2,...,m at optimality of the previous iteration. Initial values at iteration one are $s_{ik}^{(N-1)*} = s_{ik}^{(0)*} = x_{ik}$.

[1]The form of the constrained facet analysis model used in the first iteration is similar to the Data Envelopment Analysis (DEA) model of Charnes, Cooper and Rhodes (19); however the non-Archimedean infinitesimal quantities are not required.

The following linear programming model is used in constrained facet analysis for each iteration N = 1, 2,....M:

Primal

$$\text{Max} \quad f_k^{(N)} = \sum_{r=1}^{s} \mu_{rk}^{(N)} s_{rk}^{(N-1)*} + \sum_{i=1}^{m} \nu_{ik}^{(N)} s_{ik}^{(N-1)*} \qquad (1)$$

$$\text{s.t.} \quad \sum_{r=1}^{s} \mu_{rk}^{(N)} y_{rj} - \sum_{i=1}^{m} \nu_{ik}^{(N)} x_{ij} = 0 \quad \text{for } j \in E_k^{(N)}$$

$$\sum_{r=1}^{s} \mu_{rk}^{(N)} y_{rj} - \sum_{i=1}^{m} \nu_{ik}^{(N)} x_{ij} \leq 0 \quad \text{for } j \in \bar{E}_k^{(N)}$$

$$\sum_{i=1}^{m} \nu_{ik}^{(N)} x_{ik} = 1$$

$$\mu_{rk}^{(N)}, \nu_{ik}^{(N)} > 0$$

where

$E_k^{(N)} \equiv$ {j/jth constraint holds with equality at optimality at iteration N-1}

$\bar{E}_k^{(N)} \equiv$ {j/jth constraint is < 0 at optimality of iteration N-1}

$E_k^{(1)} \equiv \phi$ (empty), $\bar{E}_k^{(1)} \equiv \{1, 2,...,n\}$.

The upper and lower bound efficiency measures are obtained from solution of the first and last iterative models as shown below:

$$h_k^{(1)} = f_k^{(1)} - 1 = \sum_{r=1}^{s} u_{rk}^{(1)*} y_{rk}$$

$$h_k^{(M)} = \sum_{r=1}^{s} u_{rk}^{(M)*} y_{rk}$$

The dual of model (1) above is:

Dual

$$\text{Min } \omega_k^{(N)} \tag{2}$$

$$\text{s.t.} \quad \sum_{j \in E^{(N)}} \lambda_j^{(N)} y_{rj} + \sum_{j \in \bar{E}^{(N)}} \gamma_j^{(N)} y_{rj} - s_{rk}^{(N)} = s_{rk}^{(N-1)*} \qquad r = 1,2,\ldots,s$$

$$x_{ik}\omega_k^{(N)} - \sum_{j \in E^{(N)}} \lambda_j^{(N)} x_{ij} - \sum_{j \in \bar{E}^{(N)}} \gamma_j^{(N)} x_{ij} - s_{ik}^{(N)} = s_{ik}^{(N-1)*} \qquad i = 1,2,\ldots,m$$

$$\omega_k^{(N)},\ \lambda_j^{(N)} \text{ unrestricted};\ \gamma_j^{(N)},\ s_{rk}^{(N)},\ s_{ik}^{(N)} \geq 0$$

The mathematical theory and proofs related to the development of this model can be found in Clark (20). They will not be repeated in this paper, but there are a few model characteristics which are worth noting here.

First, the efficiency measures $h_k^{(1)}$ and $h_k^{(M)}$ are scalar ratio measures. Secondly, the constraints of the primal problem insure that the maximum achievable value of these efficiency measures is 1. Furthermore, constrained facet analysis does not require that outputs or inputs have common scales or units of measurement, an important attribute when dealing with difficulties such as nonmonetary objectives and nonpurchased resources, however; all measured input and output values are required to be strictly positive. Finally, each unit is compared to others in the set which have similar input/output mixes, i.e., those units in its "neighborhood".

In short, the constrained facet analysis model can identify units which are efficient or inefficient relative to a neighborhood frontier region of actual achievement; it can provide a limited number of clues on possible causes from analysis of surplus variables and multipliers; and it is helpful in evaluating the impact of alternative mixes of inputs and outputs.

Furthermore, the information provided by the constrained facet analysis model is a major improvement over the inadequate, partial (and sometimes inaccurate) measures

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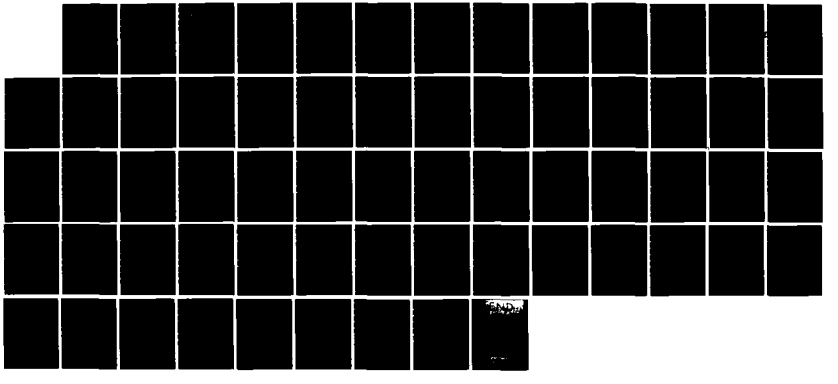
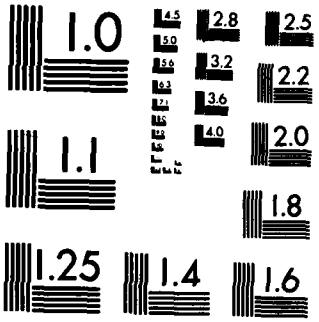
UNCLASSIFIED SEP 84 AFIT/GEM/LSM/84S-4 F/G 13/12 NL




1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0
4.5
5.0
5.6
6.3
7.1
8.0
9.0

of performance which are now typically in use in many public service organizations. In addition to its usefulness as a performance monitoring device, this efficiency analysis tool opens the door for further development and growth in other areas of planning, resource allocation and decision support.

Reprinted from: "Constrained Facet Analysis, A New Method for Evaluating Local Frontiers of Efficiency and Performance" (11)

Appendix F: AFESC Data Collection Package to Major Commands

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS AIR FORCE ENGINEERING AND SERVICES CENTER
TYNDALL AIR FORCE BASE, FL 32403

REPLY TO ATTN OF: DEM

10 APR 1984

SUBJECT: Data Collection for Fire Department Project

TO:

HQ AFCC/DEF	HQ AFLC/DEF	HQ ATC/DEF
HQ AU/DEF	HQ AFSC/DEF	HQ MAC/DEF
HQ SAC/DEF	HQ SPACECOM/DEF	HQ TAC/DEF
HQ USAFA/DEF	HQ AFRES/DEF	

1. One of the requirements of Project IMAGE is to develop a method to measure productivity (efficiency/effectiveness) for each Civil Engineering function. The task of measurement for the Fire Department has been undertaken as a Masters Degree thesis project by two students at the Air Force Institute of Technology. This function promises to be the most difficult to evaluate because of its total service mission.

2. Major Susanne M. Waylett and 1st Lieutenant Timothy A. Byers are using a new methodology developed at the University of Texas called Constrained Facet Analysis which is the only system that has the ability to produce an evaluation using multiple inputs and multiple outputs. They have identified the data elements listed on the attached form as those needed for the system.

3. Request that you collect this data for FY 83 from each CONUS base in your command, not including those Fire Departments that are contracted, and return to HQ AFESC/DEMG by 23 April 1984. Considerable effort was expended to develop a set of instructions that fully explains each element and the source document for the data. Organizations should be reminded to carefully read the instructions prior to filling out the data form. Questions concerning the data request may be directed to Major Waylett or Lt Byers by leaving a message at AUTOVON 785-4437.

FOR THE COMMANDER

GEORGE R. TATE, Colonel, USAF
Director, Operations and Maintenance

1 Atch
Data Request Form w/atch

Use the following instructions to fill out data request form. All data must be for Fiscal year 83 (not calendar year). Put N/A where data not available.

1. Self-explanatory.
2-4. See atch 1 to instructions for codes.
5-8. Self-explanatory.
9-10. Includes aerospace vehicle incidents and emergency landings from AF Form 1528.
11-12. Total number of building fire loss/number loss from AF Form 1528.
13-14. Housing fire loss/number loss responses from AF Form 1528.
15-16. Other building fire loss/number loss responses excluding housing (housing + other = total building fire responses).
17-18. Total fuel spill responses (class II and class III) from AF Form 1528.
19-20. From AF Form 1528.
21-22. Includes vehicle/equipment fires, flightline ground fires, runway foaming, bomb threats, false alarms, and other emergency responses from AF Form 1528.
23-24. Includes broken arrow exercises, aircraft hijack exercises, aeromedical movements, aircraft fueling /defueling, aircraft engine starts, aircraft maintenance, weapon load/download, alerts (aerospace vehicles) and mass aircraft movements from AF Form 1528.
25-26. Includes fuel systems repair, missile maintenance, missile launch and other standbys from AF Form 1528.
27-28. Includes aircraft rescue drill with fire and aircraft rescue (egress) on assigned aircraft from AF Form 1528.
29-30. Includes structural pre-fire plan drills, dry hose and wet hose lays from AF Form 1528.
31-32. From AF Form 1528.
33-34. Total number of Prime BEEF exercises and total number of manhours alloted to Prime BEEF training.
35-36. Total documents reviewed including specifications, work requests, work orders, fire safety deficiency reports. Technical Services Chief should estimate number and manhours.
37-38. Technical Services Chief estimate number and manhours for work requests and work orders only.
39-40. Technical Services Chief estimate number and manhours for Civil Engineering Design support only.
41-43. Total reported for FY 83 from AF Forms 278.
44-46. FY building fire loss ÷ total number of reportable fires from AF Form 1528.
47-49. Total number of inspections for FY 83.
50-54. Self-explanatory.
55-56. Includes fire prevention lectures, films and first aid demonstrations.

57. From Base Air Traffic Control office.
58. Real property records.
59-63. From PCN SH069-L12 RC Managers Expense Report
59. Total $ for FY 83 (EEIC 39XXX excluding 397).
60. Total $ for FY 83 (EEIC 2XXXX excluding 20000)
61. Total $ for FY 83 (Include fuel, foam, personal gear, office supplies, etc. EEIC 609, 612, 619, 693; exclude 60900).
62. Total $ for equipment for FY 83 (exclude vehicles, EEIC 628)
63. Total $ for contracted services for FY 83 (EEIC 533, 569).
64-73. Use BEAMS retrieval shown in atch 2 to complete data.
64-65. Military + civilian M/H Fire Dept for total. Total available is total minus the Indirect for Operations.
66-67. Total is Operations military + civilian. Total available is Direct military + civilian for Operations.
68-69. Total is Tech Svc military + civilian. Total available is equal to total for Tech Svc.
70-71. Total is Total M/H Fire Dept for civilians. Total available is the total minus the indirect for civilians for Operations.
72-73. Total is Total M/H Fire Dept for military. Total available is the total minus the indirect for military for Operations.
74-83. Total includes authorized as of fourth quarter 83 for each skill level. Total available is the assigned in each skill level at the end of FY 83.
84. Total real property value from Real Property records.
85. Housing value from Real Property records.
86. Total real property minus Housing value.
87. From CA/CRL.
88. From Real Property records.
89. From Public Affairs Office.
90. From Real Property records.
91. From Real Property records.
92. Self-explanatory.
93, 96, 99, 102. Number assigned.
94, 97, 100, 103. Value of vehicles assigned (from vehicle records).
95, 98, 101, 104. Subtract out-of-commission hours from the value:(24 hours X 365 days X number of vehicles assigned).
105, 106, 107. From AF Form 278.

CONSTRAINED FACET ANALYSIS INPUT/OUTPUT MEASURES
FOR AF FIRE DEPARTMENTS

DEMOGRAPHIC DATA

Base Name (1) _____

State Code (2) _____ Region Code (3) _____ MAJCOM Code (4) _____

Base Civil Engineer's Name (5) _____ Autovon (6) _____

Fire Chief's Name (7) _____ Autovon (8) _____

	NUMBER	MANHOURS
Aerospace Vehicle Responses	(9) _____	(10) _____
Building Fire Responses	(11) _____	(12) _____
Housing	(13) _____	(14) _____
Other	(15) _____	(16) _____
Fuel Spill Responses	(17) _____	(18) _____
Mutual Aid Responses	(19) _____	(20) _____
Other Responses	(21) _____	(22) _____
Aircraft Standbys	(23) _____	(24) _____
Other Standbys	(25) _____	(26) _____
Aircraft Rescue Drills	(27) _____	(28) _____
Structural Drills	(29) _____	(30) _____
Classroom Training	(31) _____	(32) _____
Prime BEEF Training	(33) _____	(34) _____
Documents Reviewed	(35) _____	(36) _____
In-service Work	(37) _____	(38) _____
Contract Work	(39) _____	(40) _____

	HOUSING	OTHER	TOTAL
Building Fire Loss ($)	(41) $ _____	(42) $ _____	(43) $ _____
Loss per Reportable Fire ($)	(44) $ _____	(45) $ _____	(46) $ _____
Total # of Inspections	(47) _____	(48) _____	(49) _____

Total # of Inspectors (50) _____

Fire Related Deaths: Base Populace (51) _____ Firefighters (52) _____

Fire Related Injuries: Base Populace (53) _____ Firefighters (54) _____

Total # of Prevention Presentations: on-base (55) _____ off-base (56) _____

Total # of Landings and Take-offs (57) _____

Land Area (acres) (58) _____

Expenditure ($)

Civilian Pay (59) $ _____ Military Pay (60) $ _____

Supplies (61) $ _____ Equipment (62) $ _____

Contracted Services (63) $ _____

MANHOURS	TOTAL	TOTAL AVAILABLE
Total Fire Department	(64) _____	(65) _____
Operations	(66) _____	(67) _____
Technical Services	(68) _____	(69) _____
Civilian	(70) _____	(71) _____
Military	(72) _____	(73) _____
Skill Level		
57190	(74) _____	(75) _____
57170	(76) _____	(77) _____
57150	(78) _____	(79) _____
57130 - 57110	(80) _____	(81) _____
57100	(82) _____	(83) _____

Real Property Value at Risk (excluding aircraft) (84) $ _____

Housing Value at Risk (85) $ _____

Industrial Structure Value at Risk (86) $ _____

Value of Equipment (other than vehicles) (87) $ _____

Value of Fire Department Facilities (88) $ _____

Effective Base Population (89) _____

Number of Active Runways (90) _____

Number of Housing Units (91) _____

Number of Fire Stations (92) _____

VEHICLES	NUMBER	VALUE ($)	AVAILABLE HRS
Total	(93) _____	(94) _____	(95) _____
Crash/Firefighting (P-15, P-2, P-4)	(96) _____	(97) _____	(98) _____
Structural Firefighting Pumpers (P-8, P-12)	(99) _____	(100) _____	(101) _____
Other (P-10, P-13, F-6, Pickups, P-6, Aerial)	(102) _____	(103) _____	(104) _____

Aircraft Value at Risk (105) $ _____ Aircraft Incidents (106) _____

Aircraft Loss (107) $ _____

BEAMS Retrieval for Items 64 - 73.

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R,TEXT FIRE-DEPT
000010 INPUT CHF-CLU
000020 OUTPUT TO PRINTER
000030 USE SHOP PIC X(10) AS 'FIRE PROT' IF B-CT-CTR = '425' ELSE 'OPERATIONS'
000040 IF B-CT-CTR = '426' ELSE 'TECH SVC' IF B-CT-CTR = '427'
000050 USE TYPE-LUC PIC X(8) AS 'INDIRECT' IF B-LUC =  '31' '33'
000060 ELSE 'DIRECT'
000070 SELECT IF B-CTL-INSTL = 'XXXX' AND B-TRANS-ID = 'CLU' AND B-CT-CTR
000080 = '425' '426' '427' AND B-LUC NOT = '10' '38'
000100 SORT SHOP TYPE-LUC B-LUC B-MIL-HRS B-CIV-HRS
000110 BREAK ON SHOP ON TYPE-LUC
000140 TITLE ON TOP EACH PAGE 'FIRE DEPT MANHOURS' THEN SKIP 3 LINES
000150 'SHOP' POS 1 'MIL-HRS' POS 24 'CIV-HRS' POS 37 THEN SKIP 3 LINES
000170 DISPLAY ON TYPE-LUC TYPE-LUC POS 7 TOTAL B-MIL-HRS POS 19 TOTAL
000180 B-CIV-HRS POS 33 THEN SKIP 2 LINES
000190 DISPLAY ON SHOP SHOP POS 1 TOTAL B-MIL-HRS POS 21 TOTAL B-CIV-HRS POS 34
000200 THEN SKIP 5 LINES
000300 DISPLAY ON END OF REPORT AFTER SKIP 3 'TOTAL M/H FIRE DEPT' POS 1
000320 THEN SKIP 1 LINES TOTAL B-MIL-HRS POS 21 TOTAL B-CIV-HRS POS 34
000340 END-OF-TEXT
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NOTE: ON LINE 000070, REPLACE 'XXXX' WITH YOUR APPLICABLE CONTROL INSTALLATION

GEOGRAPHIC REGIONS

The United States mainland, excluding Alaska, may be divided into seven main geographic regions. The following geographic groupings of states are based on the states' similarities in climate, physical features, economy, people, traditions, and history. Alaska and Hawaii are separate geographic regions. WORLD BOOK has separate articles on each of the 50 states and on the regions listed below.

Geographic Regions of the United States

Major Command	MAJCOM CODE
AFCC	1
AFLC	2
ATC	3
AU	4
AFSC	5
MAC	6
SAC	7
SPACECOM	8
TAC	9
USAFA	10
AFRES	11

STATE	STATE CODE	REGION CODE
Alabama	1	6
Arizona	2	7
Arkansas	3	6
California	4	4
Colorado	5	5
Connecticut	6	3
Delaware	7	6
Florida	8	6
Georgia	9	6
Idaho	10	5
Illinois	11	2
Indiana	12	2
Iowa	13	2
Kansas	14	2
Kentucky	15	6
Louisiana	16	6
Maine	17	3
Maryland	18	6
Massachusetts	19	3
Michigan	20	2
Minnesota	21	2
Mississippi	22	6
Missouri	23	2
Montana	24	5

STATE	STATE CODE	REGION CODE
Nebraska	25	2
Nevada	26	5
New Hampshire	27	3
New Jersey	28	1
New Mexico	29	7
New York	30	1
North Carolina	31	6
North Dakota	32	2
Ohio	33	2
Oklahoma	34	7
Oregon	35	4
Pennsylvania	36	1
Rhode Island	37	3
South Carolina	38	6
South Dakota	39	2
Tennessee	40	6
Texas	41	7
Utah	42	5
Vermont	43	3
Virginia	44	6
Washington	45	4
West Virginia	46	6
Wisconsin	47	2
Wyoming	48	5

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                CFA   MODEL EFF    AIR    FORCE FIRE  DEPT
                63        42    30
                01        02        03        04        05        06        07
                08        09        010       011       012       013       014
                015       016       017       018       019       020       021
                022       023       024       025       026       027       028
                029       030       031       032       033       034       035
                036       037       038       039       040       041       042
                I1        I2        I3        I4        I5        I6        I7
                I8        I9        I10       I11       I12       I13       I14
                I15       I16       I17       I18       I19       I20       I21
                I22       I23       I24       I25       I26       I27       I28
                I29       I30
1 020020001 WRIGHT PATTERSON
1 020020001 70.       22.       11.       11.       215.      9.        1646.
1 020020001 720.      850.      78.       203.      1040.     80.       671.
1 020020001 154.      720.      .000085   .000011    .00001   .000937   .000203
1 020020001 .000279   2149.     2837.     4986.     1.        999999.   999999.
1 020020001 .333333   202.      28.       121960.   8145.     50333.    93210.
1 020020001 32000.    4.        2347.     5.        0.        999999.   999999.
1 020020001 15.       298700.   34500.    257329.   9400.     14300.    429028.
1 020020001 374024.   36032.    337716.   91310.    1.        18.       60.
1 020020001 54.       2.        3636.     81500.    22.       280716.   184701.
1 020020001 3.        136326.   25374.    6.        709765.   48701.      13.
1 020020001 734140.   110653.
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1 020070002 KELLY
1 020070002 159.     4.       0.       4.       177.     1.       805.
1 020070002 2035.    71.      64.      183.     903.     0.       2941.
1 020070002 430.     236.     999999.  .000909  .000909  999999.  .003636
1 020070002 .003636  545.     5505.    6050.    999999.  999999.  999999.
1 020070002 999999.  2728.    38.      124310.  4156.    16202.   9794.
1 020070002 27613.   2.       414.     5.       0.       999999.  999999.
1 020070002 10.      211453.  1613.    105108.  58921.   0.       295680.
1 020070002 259200.  26880.   28310.   267370.  2.       12.      58.
1 020070002 24.      0.       1831.    124129.  19.      284449.  159016.
1 020070002 4.       93668.   32551.   4.       397220.  69290.   11.
1 020070002 510592.  93313.
1 020050003 HILL
1 020050003 448.     2.       0.       2.       396.     1.         1488.
1 020050003 2096.    592.     122.     106.     579.     20.        2476.
1 020050003 2262.    214.     999999.  .000699  .000699  999999.  .001399
1 020050003 .001399  1419.    8378.    9797.    999999.  999999.  999999.
1 020050003 999999.  1655.    25.      140215.  6666.    29593.   17774.
1 020050003 20604.   1.       1145.    2.       2600.    .333333  .009708
1 020050003 10.      240615.  36765.   76418.   6390.    363.     349856.
1 020050003 262656.  24960.   271763.  78093.   1.       14.      65.
1 020050003 17.      0.       3094.    105800.  17.      222199.  146880.
1 020050003 4.       153543.  34560.   5.       525785.  43200.   8.
1 020050003 160777.  69120.
1 020040004 MC CLELLAN
1 020040004 103.     5.       2.       3.       19.      0.       0.
1 020040004 99.      42.      74.      69.      275.     0.       444.
1 020040004 80.      364.     .000057  .000690  .000053  .000114  .001379
1 020040004 .000105  812.    1836.    2648.    999999.  999999.  999999.
1 020040004 999999.  540.     0.       84000.   3178.    21386.   12394.
1 020040004 19366.   2.       656.     2.       1422.    .5       .002857
1 020040004 13.      184000.  0.       104755.  71855.   18376.   0.
1 020040004 0.       0.       0.       0.       0.       0.       0.
1 020040004 0.       0.       2291.    194923.  16.      225005.  140160.
1 020040004 3.       136326.  25127.   4.       404559.  34286.   9.
1 020040004 482237.  80747.
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1 030070007 LACKLAND
1 030070007 0.       3.       0.       36.      13.      0.       522.
1 030070007 52.      15.       24.     57.      834.     27.      3076.
1 030070007 220.     65.      999999.  .027701  .002771  999999.  .011111
1 030070007 .011111  3137.    666.     3839.    999999.  999999.  999999.
1 030070007 999999.  694.     20.      52.      6784.    999999.  15615.
1 030070007 29076.   0.       725.     3.       0.       999999.  999999.
1 030070007 8.       42260.   36070.   106420.  5917.    23614.   172416.
1 030070007 141696.  19200.   69571.   102845.  0.       5.       35.
1 030070007 15.      1.       1162.    30700.   10.      44486.   80690.
1 030070007 0.       0.       0.       3.       312545.  20872.   7.
1 030070007 132316.  59718.
1 030070008 GOODFELLOW
1 030070008 0.       0.       0.       2.       2.       0.       269.
1 030070008 0.       8.       0.       52.      318.     6.       50.
1 030070008 25.      20.      999999.  .006667  .006667  999999.  .02
1 030070008 .006667  31.      801.     832.     999999.  999999.  999999.
1 030070008 999999.  128.     0.       0.       1108.    2272.    365.
1 030070008 3067.    0.       96.      1.       0.       999999.  999999.
1 030070008 3.       25122.   39369.   12429.   331.     2369.    105600.
1 030070008 86400.   5760.    38400.   67200.   0.       7.       19.
1 030070008 10.      0.       974.     10034.   6.       37263.   49149.
1 030070008 0.       0.       0.       3.       327175.  23525.   3.
1 030070008 45452.   25624.
1 030050009 LOWRY
1 030050009 0.       5.       4.       1.       14.      0.       353.
1 030050009 0.       1.       0.       52.      162.     6.       500.
1 030050009 450.     50.      .000144  .004444  .000139  .000575  .004444
1 030050009 .000697  559.     1358.    1917.    999999.  999999.  999999.
1 030050009 999999.  174.     2.       13.      1863.    10616.   13845.
1 030050009 18000.   0.       1085.    1.       0.       999999.  999999.
1 030050009 4.       43631.   40652.   23236.   6560.    9721.    152448.
1 030050009 131328.  9600.    74668.   77780.   1.       10.      27.
1 030050009 6.       0.       114730.  25700.   7.       39291.   0.
1 030050009 0.       0.       0.       3.       290202.  0.       4.
1 030050009 72706.   0.
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1 030060010 COLUMBUS
1 030060010 240.      80.       15.       65.       29.       2.        79.
1 030060010 66.       31.       96.       105.      910.      6.        155.
1 030060010 146.      9.        999999.   .000108   .000108   999999.   .000325
1 030060010 .000325   417.     545.      962.      999999.   999999.   999999.
1 030060010 999999.   108.      2.        501543.   4410.     7909.     11799.
1 030060010 3639.     39        820.      2.        0.        1.        .000975
1 030060010 4.        43685.    74789.    103796.   4677.     238.      196934.
1 030060010 176974.   10288.    55094.    141839.   0.        15.       26.
1 030060010 19.       1.        2965.     11317.    15.       169199.   124830.
1 030060010 4.        119751.   33288.    2.        198610.   16640.    9.
1 030060010 295875.   74898.
1 030070011 LAUGHLIN
1 030070011 858.      3.        4.        54.       110.      5.        181.
1 030070011 2061.     23.       74.       32.       420.      9.          0.
1 030070011 0.        0.        999999.   999999.   999999.   999999.   999999.
1 030070011 999999.   94.       718.      812.      999999.   999999.   999999.
1 030070011 999999.   147.      26.       485398.   5338.     7193.     2712.
1 030070011 3400.     3.        608.      1.        0.        999999.   999999.
1 030070011 3.        67091.    70000.    183283.   12320.    4449.     202368.
1 030070011 165888.   7680.     81509.    120859.   1.        7.        50.
1 030070011 7.        0.        980.      28700.    15.       94452.    114824.
1 030070011 4.        68868.    31676.    2.        121530.   7388.     9.
1 030070011 944519.   75760.
1 030070012 REESE
1 030070012 266.      15.       11.       4.        85.       5.        3.
1 030070012 35.       4176.     56.       58.       586.      152.      149.
1 030070012 97.       52.       999999.   .001745   .001745   999999.   .001745
1 030070012 .001745   24.       97.       121.      999999.   999999.   999999.
1 030070012 999999.   750.      7.        507321.   6687.     6440.     5113.
1 030070012 3247.     4.        407.      2.        0.        999999.   999999.
1 030070012 3.        72436.    49474.    94985.    5416.     1155.     190848.
1 030070012 165888.   7680.     93860.    96988.    0.        9.        34.
1 030070012 17.       1.        2568.     60400.    15.       128067.   130437.
1 030070012 4.        89394.    36134.    2.        198423.   17114.    9.
1 030070012 188301.   78262.
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1 030060013 KEESLER
1 030060013 46.       5.        6.        47.       30.       0.        357.
1 030060013 656.      25.       38.       40.       753.      0.        536.
1 030060013 97.       20.       .000030   .000332   .000028   .000180   .001658
1 030060013 .000162   481.     1587.     2068.     999999.   999999.   999999.
1 030060013 999999.   265.      0.        12939.    1610.     39055.    26022.
1 030060013 26900.    1.        1957.     1.        18100.    999999.   999999.
1 030060013 5.        67886.    55175.    75723.    22317.    13807.    153432.
1 030060013 136295.   13576.    82656.    86920.    0.        8.        32.
1 030060013 23.       1.        0.        28300.    12.       45182.    101605.
1 030060013 3.        10253.    25401.    2.        198610.   16934.    7.
1 030060013 150669.   59270.
1 030070014 SHEPPARD
1 030070014 226.      113.      9.        3.        106.      0.        256.
1 030070014 46.       388.      30.       45.       570.      15.       30.
1 030070014 41.       15.       .000359   .002410   .000312   .003236   .007246
1 030070014 .002237   1584.     480.      2024.     999999.   999999.   999999.
1 030070014 999999.   7498.     0.        315704.   5249.     17235.    13629.
1 030070014 12011.    3.        1286.     1.        8189.     999999.   999999.
1 030070014 8.        94024.    60075.    8120.     67867.    135.      312908.
1 030070014 279436.   15390.    136842.   176065.   1.        9.        40.
1 030070014 3.        1.        2001.     174005.   17.       81954.    110582.
1 030070014 4.        58416.    35040.    2.        44450.    8163.     8.
1 030070014 190929.   67379.
1 030070015 RANDOLPH
1 030070015 340.      616.      25.       209.      10.       6.        0.
1 030070015 53.       3448.     79.       81.       784.      245.      2457.
1 030070015 35.       40.       .000533   .000612   .000285   .001067   .001838
1 030070015 .000675   776.     1183.     1959.     999999.   999999.   999999.
1 030070015 999999.   776.      5.        314163.   3854.     7012.     1031.
1 030070015 11738.    3.        1019.     2.        0.        999999.   999999.
1 030070015 5.        99036.    106633.   96348.    4000.     5000.     208512.
1 030070015 179712.   13440.    62242.    146270.   0.        10.       34.
1 030070015 23.       1.        1475.     47353.    15.       135723.   129649.
1 030070015 4.        94395.    34332.    2.        198610.   17439.    9.
1 030070015 215525.   77878.
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1 030070016 WILLIAMS
1 030070016 584.      97.       0.        0.        87.       0.        189.
1 030070016 30.       10.       95.       55.       997.      19.       414.
1 030070016 408.      75.       .018181   .001887   .001709   .018181   .003774
1 030070016 .003125   444.     792.      1236.     999999.   999999.   999999.
1 030070016 999999.   4648.     1.        616541.   4066.     8317.     9647.
1 030070016 10500.    3.        806.      2.        0.        1.        .357143
1 030070016 4.        59640.    62171.    12851.    183453.   4740.     530880.
1 030070016 423760.   12480.    209800.   232800.   1.        14.       30.
1 030070016 13.       0.        3744.     57300.    14.       113575.   102934.
1 030070016 4.        68868.    30975.    2.        213240.   7170.     8.
1 030070016 233821.   64789.
1 030020017 CHANUTE
1 030020017 3.        8.        19.       32.       10.       1.        373.
1 030020017 27.       8.        9.        63.       177.      0.        1117.
1 030020017 1081.     36.       .00012.   .005435   .000118   .000240   .016393
1 030020017 .000588   962.      747.      1709.     999999.   999999.   999999.
1 030020017 999999.   67.       15.       54.       2174.     13841.    17096.
1 030020017 14968.    0.        1508.     1.        0.        999999.   999999.
1 030020017 4.        17458.    59495.    72004.    33209.    5566.     124800.
1 030020017 103680.   11520.    27395.    97405.    2.        4.        23.
1 030020017 12.       0.        1279.     27400.    7.        11038.    60480.
1 030020017 0.        0.        0.        3.        79425.    25920.    4.
1 030020017 30951.    34560.
1 040060020 MAXWELL/GUNTER
1 040060020 36.       5.        4.        1.        46.       0.        572.
1 040060020 178.      36.       54.       90.       862.      7.        900.
1 040060020 225.      40.       .000042   .002500   .000036   .000167   .002500
1 040060020 .000157   1034.     2809.     3843.     999999.   999999.   999999.
1 040060020 999999.   6951.     340.      3969.     4490.     13057.    2609.
1 040060020 9400.     2.        1073.     2.        2159.     1.        1.
1 040060020 8.        66354.    91831.    59098.    354.      8891.     378776.
1 040060020 298051.   8056.     121208.   257568.   2.        12.       40
1 040060020 27.       0.        1611.     56100.    15.       133564.   126740.
1 040060020 3.        77092.    24456.    4.        411850.   32995.    8.
1 040060020 152861.   69289.
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1 050070021 HROOKS
1 050070021 0.       626.     50.      273.     4.       0.       6.
1 050070021 11.      26.      0.       146.     796.     240.     611.
1 050070021 277.     4.       999999.  999999.  999999.  999999.  999999.
1 050070021 999999.  147.     2759.    2766.    999999.  999999.  999999.
1 050070021 999999.  86.      0.       11.      1320.    5089.    8743.
1 050070021 2600.    0.       170.     1.       0.       999999.  999999.
1 050070021 2.       32453.   27358.   14000.   1000.    13000.   216480.
1 050070021 210240.  6240.    93613.   122867.  1.       4.       25.
1 050070021 6.       0.       2500.    28400.   7.       12464.   76339.
1 050070021 0.       0.       0.       3.       99809.   30839.   4.
1 050070021 24827.   45500.
1 050040022 EDWARDS
1 050040022 176.     479.     96.      409.     263.     4.       690.
1 050040022 1135.    1192.    60.      243.     1702.    57.      485.
1 050040022 1408.    317.     .013699  .000044  .000044  .027397  .000355
1 050040022 .000351  153.     2627.    2780.    999999.  999999.  999999.
1 050040022 999999.  137.     14.      38209.   307972.  33173.   26000.
1 050040022 8704.    19.      1984.    5.       151002.  .166667  .000341
1 050040022 8.       180477.  111871.  114626.  0.       50000.   441444.
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1 050040022 14.      0.       3771.    61200.   31.      304726.  22879.
1 050040022 7.       187880.  8131.    6.       753655.  7621.    17.
1 050040022 415107.  7126.
1 050060023 EGLIN
1 050060023 572.     15.      8.       7.       606.     7.       1825.
1 050060023 1707.    5436.    365.     426.     4141.    1064.    4796.
1 050060023 178.     365.     .000267  .000017  .000016  .001869  .000117
1 050060023 .000110  1238.    3241.    4479.    999999.  999999.  .2
1 050060023 999999.  393.     2.       87242.   456000.  130300.  133583.
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1 050060023 6.       95066.   242561.  218585.  32106.   24617.   649608.
1 050060023 619016.  22832.   132644.  516964.  5.       25.      69.
1 050060023 97.      1.       3124.    323100.  35.      409587.  264682.
1 050060023 12.      282929.  84889.   9.       981525.  69065.   14.
1 050060023 285063.  110728.
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1 050060024 PATRICK
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1 050060024 174.     49.      44.      23.      634.     104.     443.
1 050060024 53.      390.     .000310  999999.  .000310  .001240  999999.
1 050060024 .001240  373.     918.     1291.    999999.  999999.  .166667
1 050060024 999999.  90.      13.      21518.   2107.    62124.   115316.
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1 050060024 4.       71319.   68828.   103921.  6185.    25266.   212736.
1 050060024 193536.  9600.   90252.   122484.  1.       20.      43.
1 050060024 17.      1.       1338.    38349.   15.      150877.  100132.
1 050060024 3.       102534.  25416.   3.       312545.  24396.   9.
1 050060024 170890.  50320.
1 050030025 HANSCOM
1 050030025 6.       10.      319.     0.       7.       11.      92.
1 050030025 27.      4.       4.       86.      510.     70.      972.
1 050030025 936.     6.       .000097  .000402  .000078  .000662  .000486
1 050030025 .000280  132.     336.     468.     999999.  999999.  999999.
1 050030025 999999.  260.     5.       1300.    779.     10329.   11600.
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1 050030025 4.       53388.   29406.   17428.   12000.   9132.    129460.
1 050030025 108814.  7662.   53953.   77647.   1.       5.       35.
1 050030025 3.       0.       856.     52200.   8.       61330.   70080.
1 050030025 2.       34434.   15999.   2.       213240.  16872.   4.
1 050030025 55719.   33991.
1 060020030 SCOTT
1 060020030 73.      121.     3.       0.       43.      0.       186.
1 060020030 2247.    24.      131.     83.      582.     77.      962.
1 060020030 932.     30.      .000528  .000833  .000323  .001582  .002500
1 060020030 .000969  421.     889.     1310.    999999.  999999.  999999.
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1 060020030 4.       21975.   15905.   51482.   3040.    52009.   231774.
1 060020030 219294.  12480.   71462.   160312.  0.       13.      36.
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1 060020030 4.       105561.  29282.   2.       128869.  16493.   6.
1 060020030 81282.   51060.
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1 060060031 ANDREWS
1 060060031 39.       1.        10.       4.        47.       15.       158.
1 060060031 126.      9.        333.      45.       1062.     118.      1950.
1 060060031 1800.     150.      .000360   .000716   .000240   .003597   .002865
1 060060031 .001595   9.        1776.     1785.     999999.   999999.   999999.
1 060060031 999999.   380.      20.       97500.    7507.     24353.    42099.
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1 060060031 5.        108901.   75323.    125251.   32864.    8075.     277248.
1 060060031 252288.   11520.    128953.   148295.   1.        11.       50.
1 060060031 15.       1.        1284.     69697.    15.       202039.   97511.
1 060060031 4.        153543.   32673.    3.        297915.   25589.    8.
1 060060031 187045.   68249.
1 060060032 DOVER
1 060060032 89.       11.       1.        14.       18.       5.        464.
1 060060032 180.      248.      30.        69.      844.      3.        118.
1 060060032 38.       70.       .000151   .00006    .000043   .000539   999999.
1 060060032 .000539   1236.     121.      1357.     999999.   999999.   999999.
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1 060060032 4.        38530.    58810.    67601.    12266.    30134.    173424.
1 060060032 143528.   9776.     65816.    107608.   0.        7.        43.
1 060060032 8.        1.        999999.   35301.    14.       184755.   108740.
1 060060032 3.        136314.   24721.    2.        213240.   16161.    9.
1 060060032 271161.   67858.
1 060060033 HURLBURT
1 060060033 85.       114.      1.        4.        39.       11.       174.
1 060060033 128.      46.       59.       59.       239.      19.       550
1 060060033 150.      50.       .001724   .001000   .000633   .003448   .002000
1 060060033 .002532   1420.     72.       1492.     999999.   999999.   999999.
1 060060033 999999.   225.      10.       74556.    6633.     5165.     6962.
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1 060060033 3.        52401.    64348.    30517.    6641.     1235.     87459.
1 060060033 76547.    4960.     21106.    66253.    0.        8.        29.
1 060060033 23.       1.        1447.     45700.    16.       154408.   132434.
1 060060033 3.        102534.   24378.    3.        312545.   24980.    10.
1 060060033 118853.   83076.
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1 060070034 ALTUS
1 060070034 13.       9.       3.       6.       52.      1.       362.
1 060070034 338.      117.     71.      58.      865.     8.       871.
1 060070034 642.      46.      .000032  .000096  .000024  .000096  .000386
1 060070034 .000077   381.    731.     1112.    999999.  999999.  999999.
1 060070034 999999.   92.      3.       56878.   2513.    9216.    10745.
1 060070034 11250.    1.       803.     1.       0.       999999.  999999.
1 060070034 4.        75792.   46235.   97550.   6322.    0.       208512.
1 060070034 196992.   7680.    99291.   109221.  0.       11.      29.
1 060070034 22.       1.       1897.    81101.   11.      221905.  84657.
1 060070034 3.        176354.  23627.   2.       198423.  15878.   6.
1 060070034 257088.   45152.
1 060060035 POPE
1 060060035 215.      1.       0.       0.       60.      0.       0.
1 060060035 682.      0.       37.      56.      2798.    4.       53.
1 060060035 48.       5.       .003077  999999.  .003077  .003077  999999.
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1 060060035 3.        66103.   69880.   105103.  6947.    57742.   207744.
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1 060060035 5.        0.       2229.    41464.   13.      143306.  107486.
1 060060035 5.        129128.  38369.   2.       60499.   17405.   6.
1 060060035 81277.    51712.
1 060060036 LITTLE ROCK
1 060060036 498.      303.     35.      268.     70.      0.       100.
1 060060036 322.      15.      139.     128.     597.     5.       1573.
1 060060036 1546.     27.      .000020  .001198  .000020  .000080  .005988
1 060060036 .000177   879.    820.     1699.    999999.  999999.  1.
1 060060036 1.        196.     14.      230C32.  11640.   95911.   84985.
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1 060060036 3.        62051.   62320.   63388.   5988.    2981.    189649.
1 060060036 168105.   6024.    68446.   121203.  1.       14.      37.
1 060060036 13.       1.       1416.    320600.  12.      186355.  98530.
1 060060036 4.        153542.  30987.   2.       213340.  17228.   6.
1 060060036 114787.   50315.
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1 060060037 CHARLESTON
1 060060037 115.     10.       1.       9.       147.     2.       121.
1 060060037 270.     88.       32.      45.      263.     4.       975.
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1 060060037 999999.  165.      5.       134878.  3738.    9121.    13319.
1 060060037 6849.    2.       1052.    2.       0.       999999.  999999.
1 060060037 5.       52180.   79634.   131631.  5498.    5659.    165893.
1 060060037 153907.  2704.    45474.   120419.  0.       11.      36.
1 060060037 24.      1.       2007.    45700.   17.      263046.  126286.
1 060060037 6.       213418.  48451.   2.       213240.  16235.   9.
1 060060037 283036.  61550.
1 060070038 KIRTLAND
1 060070038 161.     12.       1.       11.      86.      0.       1096.
1 060070038 214.     429.      79.      125.     1510.    26.      2468.
1 060070038 730.     1738.     .001066  .000040  .000038  .001066  .000439
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1 060070038 16064.   4.       2132.    5.       28070.   .5       .009137
1 060070038 7.       160548.  63946.   248525.  6589.    24655.   339400.
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1 060070038 11.      0.       1769.    44400.   18.      228399.  142155.
1 060070038 5.       159228.  37752.   6.       580402.  47802.   7.
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1 060040039 MC CHORD
1 060040039 279.     9.       3.       6.       91.      1.       622.
1 060040039 682.     54.      157.     165.     1705.    65.      2215.
1 060040039 2090.    125.     .001350  .000027  .000026  .004049  .000349
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1 060040039 186624.  11520.   7147.    144000.  1.       14.      40.
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1 060040039 116883.  33569.
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1 070040040 BEALE
1 070040040 4.       42.       22.       20.       1.        1.        515.
1 070040040 389.     1070.     57.       127.      1288.     0.        300.
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1 070040040 210816.  7680.     113388.   116628.   2.        18.       39.
1 070040040 10.      0.        3153.     43518.    16.       179106.   140160.
1 070040040 3.       136326.   24601.    3.        213240.   25105.    10.
1 070040040 214562.  84122.
1 070040041 FAIRCHILD
1 070040041 85.      7.        3.        4.        58.       0.        482.
1 070040041 481.     1097.     112.      128.      1483.     22.       1454.
1 070040041 1298.    32.       .000534   .000030   .000028   .001603   .000059
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1 070930042 PEASE
1 070030042 79.      250.      0.        0.        274.      14.       217.
1 070030042 602.     80.       55.       65.       707.      35.       691.
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1 070030042 256251.  1907.
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1 070050043 5.        30757.    73518.    63236.    88.       11575.    204501.
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1 070050043 35.       0.        1274.     47600.    15.       122794.   128207.
1 070050043 5.        100914.   43373.    3.        141879.   24794.    7.
1 070050043 7615.     51280
1 070020044 K.I. SAWYER
1 070020044 93.       3.        3.        3.        220.      1.        214.
1 070020044 1219.     293.      73.       140.      863.      0.        540.
1 070020044 300.      65.       .004167   .001185   .000923   .008333   .003556
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1 070020044 171813.   70080.
1 070050045 F.E. WARREN
1 070050045 3.        23.       7.        56.       0.        8.        205.
1 070050045 25.       0.        20.       41.       874.      17.       30.
1 070050045 0.        30.       .003876   .000050   .000050   .003876   .000252
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1 070050045 14.       1.        1231.     30522.    9.        57840.    76715.
1 070050045 1.        17217.    8617.     3.        312545.   24523.    5.
1 070050045 93588.    43575.
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1 070020046 GRAND FORKS
1 070020046 63.       6.        6.        0.        75.       6.        479.
1 070020046 2037.     602.      54.       95.       888.      0.        701.
1 070020046 650.      40.       .000112   .000067   .000042   .001008   .000266
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1 070020046 9986.     1.        2278.     1.        0.        .5        .000076
1 070020046 3.        61665.    61629.    115878.   14866.    7648.     139304.
1 070020046 73440.    5936.     49920.    81120.    2.        8.        23.
1 070020046 23.       0.        1968.     77100.    12.       182990.   98789.
1 070020046 3.        136326.   25724.    2.        213240.   14957.    7.
1 070020046 253402.   58108.
1 070020047 WURTSMITH
1 070020047 42.       105.      65.       40.       76.       4.        100.
1 070020047 871.      148.      124.      93.       1328.     289.      841.
1 070020047 621.      50.       999999.   999999.   999999.   999999.   999999.
1 070020047 999999.   880.      786.      1666.     999999.   999999.   1.
1 070020047 999999.   138.      25.       28215.    5223.     12650.    21315.
1 070020047 8813.     1.        1342.     2.        19951.    1.        999999.
1 070020047 3.        51009.    72941.    50000.    15000.    200.      103981.
1 070020047 94060.    3968.     35820.    68160.    2.        9.        26.
1 070020047 25.       0.        2764.     51800.    13.       180000.   113880.
1 070020047 3.        136326.   105120.   2.        273240.   17520.    7.
1 070020047 171813.   70800.
1 070040048 GRISSOM
1 070040048 331.      7.        2.        5.        93.       1.        242.
1 070040048 29.       126.      70.       67.       1330.     24.       882.
1 070040048 812.      80.       .000038   .000032   .000017   .003846   .003125
1 070040048 .001724   1180.     1138.     2318.     999999.   999999.   .333333
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1 070040048 6507.     1.        1128.     1.        613.      .5        .000164
1 070040048 2.        64510.    57507.    103104.   2390.     5344.     197373.
1 070040048 176256.   9600.     101428.   95945.    1.        8.        37.
1 070040048 10.       0.        1568.     45300.    12.       182990.   93692.
1 070040048 3.        136326.   1533.     2.        213240.   13526.    7.
1 070040048 253402.   54981.
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1 070020049 454.     26.       47.       89.       2245.     28.       0.
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1 070020049 10813.   2.        711.      1.        190.      1.        .015385
1 070020049 4.       42315.    73150.    146313.   12309.    2845.     217218.
1 070020049 195890.  7728.     55348.    161870.   1.        8.        28.
1 070020049 21.      1.        2562.     47400.    15.       196707.   129600.
1 070020049 3.       136326.   25920.    3.        312545.   25920.    9.
1 070020049 291271.  77760.
1 070020051 MC CONNELL
1 070020051 168.     8.        0.        346.      99.       1.        8.
1 070020051 315.     100.      62.       61.       389.      64.       699.
1 070020051 489.     210.      999999.   .5        .5        999999.   .5
1 070020051 .5       449.      907.      1356.     999999.   999999.   999999.
1 070020051 999999.  19123.    3315.     59586.    7518.     9271.     9614.
1 070020051 4658.    2.        594.      1.        28116.    999999.   999999.
1 070020051 5.       47750.    71880.    61500.    0.        2000.     209280.
1 070020051 190080.  9600.     41856.    167424.   2.        4.        15.
1 070020051 21.      0.        3500.     80155.    12.       132290.   22611.
1 070020051 3.       93600.    8088.     3.        311900.   8106.     6.
1 070020051 75000.   6417.
1 070060052 BLYTHEVILLE
1 070060052 98.      7.        4.        3.        158.      1.        286.
1 070060052 460.     1647.     116.      75.       927.      2.        1941.
1 070060052 785.     60.       .002128   .999999.  002128    .006369   999999.
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1 070060052 999999.  570.      20.       90748.    3092.     3713.     11871.
1 070060052 7401.    1.        930.      1.        0.        999999.   999999.
1 070060052 4.       49717.    68338.    76334.    13905.    1095.     84250.
1 070060052 74934.   3328.     28153.    56097.    1.        7.        26.
1 070060052 28.      0.        2129.     36868.    14.       185025.   116465.
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1 070060052 332423.  76285.
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1 070020053 ELLSWORTH
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1 070020053 6.        58359.    62659.    164906.   22207.    12292.    194392.
1 070020053 172728.   10256.    69651.    124741.   1.        6.        45.
1 070020053 10.       0.        2840.     736300.   14.       175143.   112320.
1 070020053 3.        136326.   25920.    2.        213240.   17280.    8.
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1 070020054 WHITEMAN
1 070020054 9.        75.       21.       54.       11.       3.        140.
1 070020054 88.       96.       134.      43.       815.      6.        919.
1 070020054 419.      25.       .00004    .00007    .000026   .00008    .00035
1 070020054 .000179   480.      475.      955.      999999.   999999.   999999.
1 070020054 .5        644.      57.       13452.    135232.   10021.    15215.
1 070020054 7019.     1.        922.      1.        2116.     999999.   999999.
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1 070020054 38.       5.        18.       36.       1.        8.        21.
1 070020054 24.       0.        1521.     30691.    12.       136689.   98771.
1 070020054 3.        102534.   22209.    2.        213240.   16672.    7.
1 070020054 128318.   59890.
1 070070055 CARSWELL
1 070070055 198.      6.        20.       706.      445.      0.        229.
1 070070055 890.      191.      50.       34.       531.      129.      825.
1 070070055 681.      244.      .000227   .000163   .000095   .001368   .000327
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1 070070055 999999.   417.      76.       96272.    3263.     11894.    1087.
1 070070055 10334.    1.        807.      1.        0.        .5        .000091
1 070070055 3.        44571.    68657.    166481.   5256.     2989.     103432.
1 070070055 91117.    3640.     26134.    77298.    1.        7.        40.
1 070070055 11.       0.        3720.     73800.    13.       207204.   34252.
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1 070070055 168269.   23483.
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1 070010056 GRIFFISS
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1 070010056 3.        136326.   8360.     3.        312545.   8064.     8.
1 070010056 259751.   7456.
1 070070057 DYESS
1 070070057 170.      41.       8.        33.       343.      2.        280.
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1 070070057 139.      58.       999999.   .000009   .000009   .000048   .000048
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1 070070057 3.        56432.    71478.    71884.    169.      32990.    68033.
1 070070057 58977.    3136.     22618.    45415.    1.        5.        35.
1 070070057 25.       0.        717320.   363800.   16.       202046.   181865.
1 070070057 4.        153543.   32142.    2.        213240.   14009.    10.
1 070070057 271790.   85714.
1 070040058 VANDENBURG
1 070040058 6.        6.        5.        801.      3.        14.       216.
1 070040058 46.       117.      71.       228.      2292.     26.       540.
1 070040058 400.      140.      .000074   .001550   .000070   .000442   .009346
1 070040058 .000421   5460.     0.        5460.     999999.   999999.   999999.
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1 070040058 9.        198226.   78116.    326698.   260588.   11150.    455474.
1 070040058 427584.   27890.    242652.   245462.   2.        34.       54.
1 070040058 45.       0.        3059.     367500.   37.       335818.   24.
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1 070040058 129438.   24.
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1 070020059 881.     99.      124.     85.      326.     0.       724.
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1 070020059 .000040  1705.    1064.    2769.    999999.  999999.  999999.
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1 070020059 355752.  15704.   150358.  242962.  1.       6.       26.
1 070020059 26.      0.       1346.    59142.   13.      183441.  102703.
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1 070020059 257909.  59200.
1 070020060 OFFUTT
1 070020060 84.      13.      4.       9.       23.      1.       773.
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1 070020060 3.       136376.  25349.   3.       312545.  25601.   9.
1 070020060 164832.  76483.
1 090060061 SHAW
1 090060061 314.     4.       3.       1.       354.     4.       423.
1 090060061 421.     153.     71.      74.      714.     224.     860.
1 090060061 220.     30.      .000005  .000019  .000004  .000019  .000076
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1 090060061 101612.  3648.    19768.   91444.   2.       12.      36.
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1 090060061 3.       77092.   22718.   3.       312545.  23485.   11.
1 090060061 284882.  85155.
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1 090060062 MOODY
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1 090060062 .000106  411.     883.     1294.    999999.  999999.  .5
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1 090060062 130798.  60720.
1 090060063 SEYMOUR  JOHNSCN
1 090060063 378.     107.     0.       394.     265.     1.       0.
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1 090060063 144103.  75447.
1 090070064 HOLLOMAN
1 090070064 464.     5.       2.       3.       1176.    1.       526.
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1 090070064 319595.  99266.
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1 090060065 LANGLEY
1 090060065 197.      10.       7.        3.        657.      9.        1007.
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1 090060065 131623.   77985.
1 090070066 CANNON
1 090070066 168.      1.        1.        0.        84.       8.        691.
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1 090060067 TYNDALL
1 090060067 454.      831.      0.        79.       1742.     0.        68.
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1 090060067 292108.   76291.
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1 090050069 NELLIS
1 090050069 1313.    26.       147.     169.     636.     6.       316.
1 090050069 4275.    191.      55.      85.      839.     427.     1100.
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1 090060070 HOMESTEAD
1 090060070 598.     13.       9.       4.       379.     3.       235.
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1 090060071 MYRTLE BEACH
1 090060071 237.     1.        1.       0.       152.     5.       603.
1 090060071 1945.    326.      57.      118.     995.     7.       1669.
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1 090060071 57512.   3808.     21512.   46400.   1.       8.       61.
1 090060071 10.      0.        1903.    29739.   15.      121115.  129600.
1 090060071 4.       68868.    34560.   3.       312545.  25920.   8.
1 090060071 209918.  69120.
```

Appendix H: CFA Productivity Assessment Symposium Participants

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Management
The University of Texas

Sue Waylett
Masters Candidate
Air Force Institute of Technology

CFA MODEL EFF AIR FORCE FIRE DEPT
63 12 14

	RESPONSES L AND T CIV PAY MID MHS	STANDBYS RP RISK MIL PAY LC MHS	TRNG POP MHRS EQ VAL	DOC/PRES STATIONS CPS MHRS T FAC VAL	LOSS INCDTS SVC MHS VEHS	INSPNS SUP/EGP CIV MHRS	HURTS HI MHRS MIL MHR
200200010	WRIGHT PATTERSON						
200200010	1953.	1570.	1401.	1775.	1.	4986.	113333.
200200010	121960.	50333.	32000.	5.	200000.	281029.	21.
200200010	298700.	34500.	429028.	374024.	36032.	337716.	91310.
200200010	60.	54.	3636.	81500.	22.		
200700020	KELLY						
200700020	1145.	2106.	1150.	6373.	91.	6050.	300000.
200700020	124310.	16202.	27613.	5.	200000.	164029.	14.
200700020	211453.	1613.	295680.	259200.	26880.	28310.	267370.
200700020	58.	24.	1831.	124129.	19.		
200500030	HILL						
200500030	2334.	2688.	827.	6632.	70.	9797.	300000.
200500030	140215.	29593.	20604.	2.	33333.	83171.	15.
200500030	240615.	36765.	349856.	262656.	24960.	271763.	78093.
200500030	65.	17.	3094.	105800.	17.		

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200400040 MC CLELLAN
200400040     127.     141.     418.    1428.       5.    2648.  300000.
200400040   84000.   21386.   19366.       2.   50000.  194986.       0.
200400040  184000.       0.       0.       0.       0.       0.       0.
200400040       0.       0.    2291.  194923.      16.
300700070 LACKLAND
300700070     538.      67.     942.    4075.     277.    3839.  300000.
300700070      52.      10.   29076.       3.  200000.  135951.       6.
300700070   42260.   36070.  172416.  141696.   19200.   69571.  102845.
300700070      35.      15.    1162.   30700.      10.
300700080 GOODFELLOW
300700080     271.       8.     376.     223.     667.     832.  300000.
300700080       0.    2272.    3067.       1.  200000.   15129.       7.
300700080   25122.   39365.  105600.   86400.    5760.   38400.   67200.
300700080      19.      10.     974.   10034.       6.
300500090 LOWRY
300500090     372.       1.     220.    1176.      14.    1917.  300000.
300500090      13.   10616.   18000.       1.  200000.   39517.      11.
300500090   43631.   40652.  152448.  131328.    9600.   74668.   77780.
300500090      27.       6.  114730.   25700.       7.
300600100 COLUMBUS
300600100     428.      97.    1117.     420.      11.     962.  300000.
300600100  501543.    7909.    3639.       2.  100000.  108711.      16.
300600100   43685.   74789.  196934.  176974.   10288.   55094.  141839.
300600100      26.      19.    2965.   11317.      15.
300700110 LAUGHLIN
300700110    1152.    2084.     535.     173.  200000.     812.  300000.
300700110  485398.    7193.    3400.       1.  200000.  200052.       8.
300700110   67091.   70000.  202368.  165888.    7680.   81509.  120859.
300700110      50.       7.     980.   28700.      15.
300700120 RLESE
300700120     369.    4211.     852.    1055.     174.     121.  300000.
300700120  507321.    6440.    3247.       2.  200000.  101556.      10.
300700120   72436.   49474.  190848.  165888.    7680.   93860.   96988.
300700120      34.      17.    2568.   80400.      15.
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300600130	KEESLER						
300600130	438.	681.	831.	918.	3.	2068.	300000.
300600130	12939.	39055.	26900.	1.	200000.	111847.	9.
300600130	67886.	55175.	153432.	136295.	13576.	82656.	86920.
300600130	32.	23.	0.	28300.	12.		
300700140	SHEPPARD						
300700140	701.	434.	660.	7584.	31.	2024.	300000.
300700140	315704.	17235.	12011.	1.	200000.	76122.	11.
300700140	94024.	60075.	312908.	279436.	15390.	136842.	176065.
300700140	40.	3.	2001.	174005.	17.		
300700150	RANDOLPH						
300700150	966.	3501.	1189.	3313.	29.	1959.	300000.
300700150	314163.	7012.	11738.	2.	200000.	105348.	11.
300700150	99036.	106633.	208512.	179712.	13440.	62242.	146270.
300700150	34.	23.	1475.	47353.	15.		
300700160	WILLIAMS						
300700160	957.	40.	1166.	5546.	171.	1236.	300000.
300700160	616541.	8317.	10500.	2.	100000.	201044.	15.
300700160	59640.	62171.	530880.	423760.	12480.	209800.	232800.
300700160	30.	13.	3744.	57300.	14.		
300200170	CHANUTE						
300200170	394.	35.	249.	2316.	12.	1709.	300000.
300200170	54.	13841.	14968.	1.	200000.	110779.	6.
300200170	17458.	59495.	124800.	103680.	11520.	27395.	97405.
300200170	23.	12.	1279.	27400.	7.		
400600200	MAXWELL/GUNTER						
400600200	659.	214.	1013.	8456.	4.	3843.	300000.
400600200	3969.	13057.	9400.	2.	100000.	68343.	14.
400600200	66354.	91831.	378776.	298051.	8056.	121208.	257568.
400600200	40.	27.	1611.	56100.	15.		
500700210	HROOKS						
500700210	636.	37.	1182.	978.	200000.	2766.	300000.
500700210	11.	5085.	2600.	1.	200000.	28000.	5.
500700210	32453.	27358.	216480.	210240.	6240.	93613.	122867.
500700210	25.	0.	2500.	28400.	7.		

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500400220 EDWARDS
500400220    1608.    2327.    2062.    2361.       4.    2780. 300000.
500400220   38209.   33173.    8704.       5.   16667. 164626.      10.
500400220  180477. 111871. 441444. 255447. 115408. 234733. 206711.
500400220     112.      14.    3771.   61200.      31.
500600230 EGLIN
500600230    3018.    7143.    5996.    5754.       2.    4479. 202000.
500600230   87242. 130300.   27339.       6.   16667. 275308.      31.
500600230   95066. 242561. 649608. 619016.   22832. 132644. 516964.
500600230      69.      97.    3124. 323100.      35.
500600240 PATRICK
500600240     964.     223.     805.     989.      31.    1291. 201666.
500600240   21518.   62124.   12988.       2. 200000. 135372.      22.
500600240   71319.   68828. 212736. 193536.    9600.   90252. 122484.
500600240      43.      17.    1338.   38349.      15.
500300250 HANSCOM
500300250     115.      31.     670.    2179.       8.     468. 300000.
500300250    1300.   10329.   11089.       1. 200000.   38560.       6.
500300250   53388.   29406. 129460. 108814.    7662.   53953.   77647.
500300250      35.       3.     856.   52200.       8.
600200300 SCOTT
600200300     423.    2271.     873.    6199.      32.    1310. 300000.
600200300   60148.   12273.   24391.       1. 100000. 106531.      13.
600200300   21975.   15905. 231774. 219294.   12480.   71462. 160312.
600200300      36.       1.    1188.   52500.      12.
600600310 ANDREWS
600600310     245.     135.    1558.    4300.      24.    1785. 300000.
600600310   97500.   24353.   16950.       2. 100000. 166190.      13.
600600310  108901.   75323. 277248. 252288.   11520. 128953. 148295.
600600310      50.      15.    1284.   69697.      15.
600600320 DOVER
600600320     582.     428.     946.    1037.       4.    1357. 300000.
600600320   16284.   16002.    6278.       1. 200000. 110001.       8.
600600320   38530.   58810. 173424. 143528.    9776.   65816. 107608.
600600320      43.       8.      10.   35301.      14.
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600600330	HURLBURT						
600600330	412.	174.	376.	985.	63.	1492.	300000.
600600330	74556.	5165.	5221.	1.	200000.	38393.	9.
600600330	52401.	64348.	87459.	76547.	4960.	21106.	66253.
600600330	29.	23.	1447.	45700.	16.		
600700340	ALTUS						
600700340	436.	455.	1002.	1654.	2.	1112.	300000.
600700340	56878.	9216.	11250.	1.	200000.	103872.	12.
600700340	75792.	46235.	208512.	196992.	7680.	99291.	109221.
600700340	29.	22.	1897.	81101.	11.		
600600350	POPE						
600600350	276.	682.	2895.	204.	308.	959.	300000.
600600350	12666.	7333.	9852.	1.	100000.	169792.	6.
600600350	66103.	69880.	207744.	186624.	5760.	84302.	123442.
600600350	30.	5.	2229.	41464.	13.		
600600360	LITTLE ROCK						
600600360	971.	337.	869.	3356.	2.	1699.	120000.
600600360	230032.	95911.	7000.	1.	200000.	72357.	16.
600600360	62051.	62320.	189649.	168105.	6024.	68446.	121203.
600600360	37.	13.	1416.	320600.	12.		
600600370	CHARLESTON						
600600370	393.	358.	344.	2077.	6.	478.	300000.
600600370	134878.	9121.	6849.	2.	200000.	142788.	12.
600600370	52180.	79634.	165893.	153907.	2704.	45474.	120419.
600600370	36.	24.	2007.	45700.	17.		
600700380	KIRTLAND						
600700380	1355.	643.	1740.	5173.	4.	2227.	300000.
600700380	222000.	23124.	16064.	5.	50000.	279769.	9.
600700380	160548.	63946.	339400.	342000.	2912.	217152.	138528.
600700380	33.	11.	1769.	44400.	18.		
600400390	MC CHORD						
600400390	1001.	736.	2092.	9403.	3.	810.	202000.
600400390	25496.	7102.	8678.	1.	33333.	88923.	16.
600400390	69180.	78512.	215274.	186624.	11520.	7147.	144000.
600400390	40.	13.	7067.	52064.	11.		

700400400	HEALE						
700400400	562.	1459.	1472.	7709.	1.	1941.	300000.
700400400	18250.	15634.	11651.	3.	100000.	57072.	20.
700400400	92358.	61172.	230016.	210816.	7680.	113388.	116628.
700400400	39.	10.	3153.	43518.	16.		
700400410	FAIRCHILD						
700400410	632.	1578.	1745.	3158.	3.	1935.	115000.
700400410	14100.	12592.	12301.	2.	25000.	171399.	8.
700400410	85130.	70053.	261667.	240163.	9312.	104976.	156691.
700400410	40.	26.	2643.	160800.	14.		
700300420	PEASE						
700300420	820.	682.	862.	1505.	1.	1502.	300000.
700300420	38639.	45850.	7846.	2.	200000.	101600.	16.
700300420	59820.	69990.	203710.	184982.	7592.	66444.	137265.
700300420	16.	10.	708000.	220000.	13.		
700500430	MALMSTROM						
700500430	805.	592.	1687.	908.	4.	2270.	202000.
700500430	19845.	14258.	9196.	1.	100000.	74899.	1.
700500430	30757.	73518.	204501.	186624.	11520.	38788.	165716.
700500430	22.	35.	1274.	47600.	15.		
700200440	K.I. SAWYER						
700200440	530.	1512.	1076.	1143.	92.	3335.	300000.
700200440	46500.	623686.	1100.	1.	100000.	221593.	10.
700200440	0.	0.	211584.	203904.	7680.	53736.	157848.
700200440	28.	2.	2571.	348500.	13.		
700500450	F.E. WARREN						
700500450	231.	25.	952.	236.	5.	1096.	300000.
700500450	800.	7388.	4346.	2.	200000.	64750.	5.
700500450	39150.	37010.	77641.	68916.	2816.	31257.	46834.
700500450	29.	14.	1231.	30522.	9.		
700200460	GRAND FORKS						
700200460	623.	2639.	1037.	1572.	4.	1644.	7333.
700200460	38980.	18015.	9986.	1.	50000.	138392.	10.
700200460	61665.	61629.	139304.	73440.	5936.	49920.	81120.
700200460	23.	23.	1968.	77100.	12.		

700200470	WURTSMITH						
700200470	323.	1019.	1834.	1675.	200000.	1666.	210000.
700200470	28215.	12650.	8813.	2.	100000.	65200.	11.
700200470	51009.	72941.	103981.	94060.	3968.	35820.	68160.
700200470	26.	25.	2764.	51800.	13.		
700400480	GRISSOM						
700400480	673.	155.	1491.	1919.	2.	2318.	113333.
700400480	20894.	9371.	6507.	1.	50000.	110838.	9.
700400480	64510.	57507.	197373.	176256.	9600.	101428.	95945.
700400480	37.	10.	1568.	45300.	12.		
700200490	MARCH						
700200490	588.	480.	2409.	1788.	479.	1551.	300000.
700200490	77631.	14046.	10813.	1.	100000.	161467.	10.
700200490	42315.	73150.	217218.	195890.	7728.	55348.	161870.
700200490	28.	21.	2562.	47400.	15.		
700200510	MC CONNELL						
700200510	283.	415.	576.	23836.	50000.	1356.	300000.
700200510	59586.	9271.	4658.	1.	200000.	63500.	6.
700200510	47750.	71880.	209280.	190080.	9600.	41856.	167424.
700200510	15.	21.	3500.	80155.	12.		
700600520	BLYTHEVILLE						
700600520	549.	2107.	1120.	3376.	213.	1634.	300000.
700600520	90748.	3713.	7401.	1.	200000.	91334.	8.
700600520	49717.	68338.	84250.	74934.	3328.	28153.	56097.
700600520	26.	28.	2129.	36868.	14.		
700200530	ELLSWORTH						
700200530	660.	1246.	2463.	7659.	5.	4540.	300000.
700200530	62106.	71149.	9500.	1.	25000.	199405.	7.
700200530	58359.	62659.	194392.	172728.	10256.	69651.	124741.
700200530	45.	10.	2840.	736300.	14.		
700200540	WHITEMAN						
700200540	235.	184.	998.	2064.	3.	955.	205000.
700200540	13452.	10021.	7019.	1.	200000.	75100.	9.
700200540	46300.	67991.	51.	38.	5.	18.	36.
700200540	21.	24.	1521.	30691.	12.		

700700550	CARSWELL						
700700550	878.	1081.	744.	2243.	10.	1353.	300000.
700700550	96272.	11894.	10334.	1.	50000.	174726.	8.
700700550	44571.	68657.	103432.	91117.	3640.	26134.	77298.
700700550	40.	11.	3720.	73800.	13.		
700100560	GRIFFISS						
700100560	163.	1425.	1679.	7106.	33.	565.	210000.
700100560	59861.	20629.	7722.	1.	33333.	80340.	11.
700100560	80948.	37500.	203904.	169344.	11520.	146080.	57824.
700100560	25.	31.	2212.	54700.	14.		
700700570	DYESS						
700700570	834.	824.	925.	745.	1.	2531.	203333.
700700570	106550.	25809.	6107.	1.	100000.	105043.	6.
700700570	56432.	71478.	68033.	58977.	3136.	22618.	45415.
700700570	35.	25.	717320.	363800.	16.		
700400580	VANDENBURG						
700400580	231.	163.	2617.	1260.	7.	5460.	300000.
700400580	17949.	208558.	18381.	7.	200000.	598436.	36.
700400580	198226.	78116.	455474.	427584.	27890.	242652.	245462.
700400580	54.	45.	3059.	367500.	37.		
700200590	MINOT						
700200590	614.	980.	535.	3153.	2.	2769.	300000.
700200590	33271.	14255.	14032.	1.	50000.	159181.	7.
700200590	61566.	64209.	393320.	355752.	15704.	150358.	242962.
700200590	26.	26.	1346.	59142.	13.		
700200600	OFFUTT						
700200600	893.	171.	1980.	11089.	2.	3756.	300000.
700200600	54058.	23743.	49347.	2.	50000.	179573.	8.
700200600	71718.	82059.	170352.	142786.	13182.	63030.	107322.
700200600	60.	9.	3430.	128700.	15.		
900600610	SHAW						
900600610	1095.	574.	1083.	1601.	1.	1360.	300000.
900600610	45342.	13539.	10871.	1.	200000.	66400.	15.
900600610	32831.	80533.	111212.	101612.	3648.	19768.	91444.
900600610	36.	15.	2928.	20000.	17.		

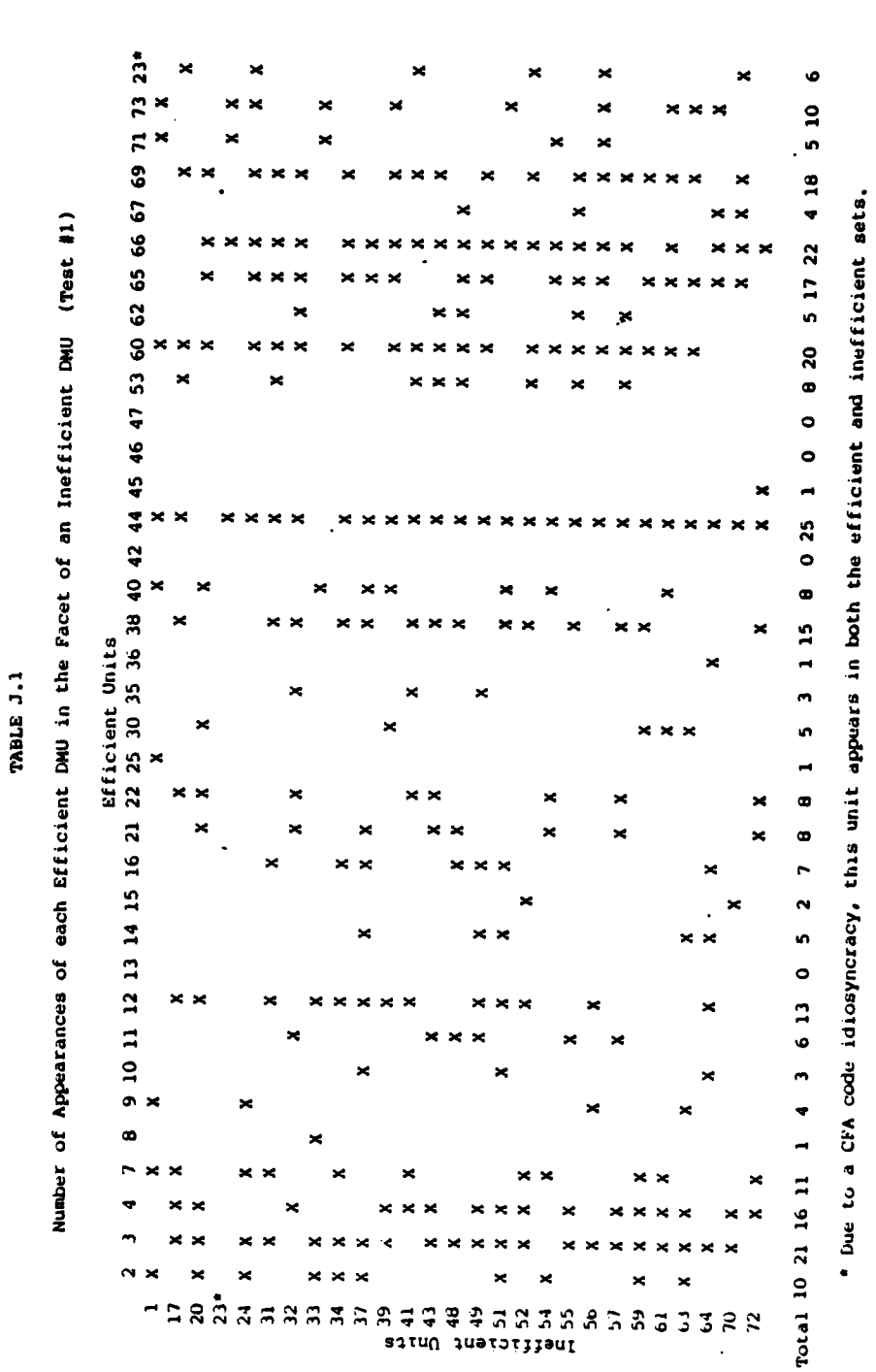
900600620	MOODY						
900600620	1981.	797.	494.	1101.	2.	1294.	205000.
900600620	27889.	6257.	8318.	1.	100000.	146011.	7.
900600620	62388.	51000.	187120.	168400.	6240.	83164.	103956.
900600620	39.	9.	3141.	38800.	12.		
900600630	SEYMOUR	JOHNSCN					
900600630	750.	4703.	403.	3058.	190.	1730.	120000.
900600630	74607.	11117.	23329.	1.	50000.	617986.	13.
900600630	53198.	39287.	112132.	97263.	5786.	46963.	65170.
900600630	42.	4.	2669.	32414.	15.		
900700640	HOLLOMAN						
900700640	2171.	6377.	3416.	12422.	107.	2889.	300000.
900700640	190000.	16708.	6040.	2.	100000.	231708.	17.
900700640	119624.	74697.	335616.	314496.	7680.	161227.	174389.
900700640	43.	36.	2636.	51835.	30.		
900600650	LANGLEY						
900600650	1871.	2334.	1786.	10910.	20.	1768.	300000.
900600650	55730.	279174.	12337.	2.	50000.	155750.	18.
900600650	59775.	72938.	235392.	214272.	13440.	87063.	148329.
900600650	45.	5.	3660.	32200.	15.		
900700660	CANNON						
900700660	944.	714.	4845.	1110.	216.	1045.	205000.
900700660	67467.	6758.	10800.	1.	33333.	76314.	14.
900700660	51341.	68138.	219264.	186624.	11520.	61765.	157499.
900700660	9.	19.	2438.	52494.	18.		
900600670	TYNDALL						
900600670	3095.	1078.	388.	1728.	3.	2002.	210000.
900600670	148913.	16074.	12700.	2.	100000.	166028.	17.
900600670	64937.	64565.	233088.	217728.	9600.	85356.	147732.
900600670	43.	10.	2301.	41495.	16.		
900500690	NELLIS						
900500690	2291.	4466.	1406.	2406.	13.	2376.	300000.
900500690	188000.	20339.	40000.	2.	33333.	185035.	17.
900500690	10.	10.	61502.	55743.	2960.	5308.	53234.
900500690	54.	13.	1310.	59930.	18.		

900600700	HOMESTEAD						
900600700	1225.	821.	1762.	7454.	5.	2412.	300000.
900600700	100000.	12817.	10651.	2.	200000.	847600.	11.
900600700	46529.	73791.	206208.	200448.	3840.	67609.	138599.
900600700	24.	8.	1664.	32923.	14.		
900600710	MYRTLE BEACH						
900600710	993.	2271.	1177.	11012.	8.	783.	300000.
900600710	3600.	6176.	6202.	1.	200000.	0.	9.
900600710	0.	0.	67912.	57512.	3808.	21512.	46400.
900600710	61.	10.	1903.	29739.	15.		
900700720	GILA BEND						
900700720	147.	14.	510.	2286.	200000.	293.	300000.
900700720	877.	0.	350.	1.	200000.	80441.	3.
900700720	24160.	15730.	79968.	69888.	2080.	39934.	39934.
900700720	10.	10.	591.	23376.	7.		
900500730	MOUNTAIN HOME						
900500730	1194.	1145.	716.	1892.	13.	2667.	205000.
900500730	3659.	11590.	10824.	1.	33333.	190.	18.
900500730	54.	66.	198120.	187720.	10400.	63336.	134720.
900500730	32.	5.	268.	24200.	14.		

Appendix J: Comparative Facet Tables

TABLE J.1

Number of Appearances of each Efficient DMU in the Facet of an Inefficient DMU (Test #1)



* Due to a CFA code idiosyncracy, this unit appears in both the efficient and inefficient sets.

TABLE J.2

Number of Appearances of Each Efficient DMU in the Facet of an Inefficient DMU (Test #4)

Inefficient Units	Efficient Units																																
	2	3	4	7	8	9	10	11	12	15	16	21	33	36	38	39	40	44	45	47	53	54	57	60	63	65	66	67	69	71	73	23*	1*
1*	X	X	X	X			X											X	X	X									X				
13	X	X		X		X												X						X		X			X	X	X		
14	X	X				X			X					X				X						X		X	X			X	X		
17	X	X		X			X		X									X		X				X			X		X				
20	X	X							X								X		X	X						X	X		X	X		X	
22	X	X		X													X	X	X	X						X			X	X			
23*		X							X									X		X		X				X	X		X	X			
24	X	X		X															X							X		X	X			X	
25	X	X		X		X											X	X						X		X	X			X			
32	X	X		X											X		X		X	X						X	X		X			X	
34	X			X			X		X	X	X							X			X			X			X		X				
35	X	X		X		X												X						X		X	X			X	X		
37	X	X	X	X			X		X									X	X										X				
41	X			X														X		X				X		X	X		X	X		X	
42	X	X							X								X		X	X						X	X		X	X		X	
43	X	X							X					X				X		X				X		X	X		X	X			
48	X	X		X		X						X					X	X								X	X					X	
49	X	X					X		X					X				X		X				X			X		X	X			
51	X	X					X		X					X				X		X						X	X		X	X			
52	X	X					X											X					X				X		X	X			
56		X					X		X									X		X		X					X		X	X			
58	X			X					X						X		X	X	X							X							X
59		X	X	X														X		X	X	X		X					X				
61	X													X		X		X								X	X		X	X	X	X	
62	X													X				X								X		X	X	X			
64		X					X		X									X		X		X					X		X	X			
72	X	X		X					X			X			X		X		X	X						X	X						
Total	23	22	3	15	0	5	9	0	14	1	1	2	0	6	3	1	8	22	9	15	2	4	1	10	0	18	19	2	21	17	5	7	1

* Due to a CFA idiosyncracy, this unit appears in both the efficient and inefficient sets

TABLE J.3

Number of Appearances of Each Efficient DMU in the Facet of an Inefficient DMU (Test #5)

Inefficient Units	Efficient Units																											
	2	3	4	7	8	9	10	11	12	21	23	36	38	40	44	45	47	53	54	57	60	63	65	66	67	69	71	73	16*
1	X			X			X		X				X		X	X							X	X		X			
13	X	X				X			X			X			X							X		X			X	X		
14	X	X				X			X			X		X	X								X				X	X	
15	X	X				X			X		X			X							X		X	X		X			
16*		X				X			X			X			X								X	X		X	X	X	
17		X		X											X		X	X			X			X		X			
20	X	X							X		X			X	X		X						X				X		
24	X	X									X												X		X	X	X		
25		X		X		X								X	X						X		X	X			X		
30		X		X		X									X						X		X			X	X		
31		X		X			X		X		X		X		X								X	X					X
32	X	X		X					X		X				X						X		X	X		X			
33		X					X								X				X					X		X	X		
34				X			X		X				X		X						X			X		X			
35		X		X		X								X	X						X		X	X			X		
37	X		X	X					X				X		X	X										X			
39		X					X		X			X			X		X						X	X		X	X		
41		X		X							X				X		X						X	X		X			
42	X	X								X	X			X			X						X	X			X		
43	X	X		X													X				X		X	X		X	X		
46	X			X					X		X		X		X		X						X	X		X			
48	X	X		X		X				X				X	X								X	X					
49				X			X		X						X			X			X			X					X
51	X	X					X		X			X		X	X		X						X				X		
52		X					X								X		X		X					X		X	X		
55		X		X			X		X		X		X										X	X		X			X
56		X							X		X				X								X	X		X	X		
58	X			X			X		X				X		X	X					X		X	X		X			
59		X	X	X											X			X	X		X					X			
61		X																					X	X	X	X	X		
62	X	X					X		X		X												X		X	X	X		
64		X				X			X			X			X						X		X	X		X	X		
70	X	X		X		X			X			X			X								X			X			X
72	X			X							X			X		X	X							X					
Total	17	27	2	19	0	10	11	0	20	2	12	7	7	9	26	4	10	3	3	0	12	0	26	24	3	24	18	2	4

* Due to a CFA code idiosyncracy this unit appears in both the efficient and inefficient sets

Appendix K: Constrained Facet Analysis Summary File

```
1            CFA MODEL EFF AIR FORCE FIRE DEPT
2               62    8    5
3             RESPONSES STANDBYS    TRNG      INSPNS     L AND T    RP RISK    POP
4              STATIONS  SUP/EQP  MI MHRS    MID MHS     LG PMS      VEHS
0 200200010                                                          .66562   .68137
1 200200010   1953.000  1570.000  1401.000  4986.000121960.000 50333.000 32000.000
2 200200010    .000021         0  .000022         0    .000000    .000001    .000006
3 200200310          0  2934.753         0  3004.256         0          0          0
4 200200310     5.000281029.000    21.000    60.000    34.000    22.000
5 200200310    .071426   .000002  .003421         0    .003864   .004730
6 200200310          0         0         0   13.094         0          0
0 200700020                                                     1.00000 1.00000
1 200700020   1145.000  2106.000  1158.000  6050.000124310.000 16202.000 27613.000
2 200700020    .000031   .000001  .000022   .000036   .000000    .000001    .000000
3 200700020          0         0         0         0         0          0          0
4 200700020     5.000164029.000    14.000    38.000    24.000    29.000
5 200700020    .127667   .000003  .002319   .007811   .000010    .000010
6 200700020          0         0         0         0         0          0
0 200500030                                                     1.00000 1.00000
1 200500030  2334.000  2684.000   827.000  9797.000140215.000 29593.000 20604.000
2 200500030    .000249   .000056  .000310   .000007   .000001    .000001    .000000
3 200500030          0         0         0         0         0          0          0
4 200500030     2.000 93171.000    15.000    65.000    17.000    27.000
5 200500030    .000010   .000001  .000323   .000010   .000010    .053429
6 200500030          0         0         0         0         0          0
0 200400040                                                     1.00000 1.00000
1 200400040   127.000   141.000   418.000  2648.000 44000.000 21386.000 19366.000
2 200400040    .000000   .000154  .000010   .000071   .000001    .000001    .000013
3 200400040          0         0         0         0         0          0          0
4 200400040     2.000194986.000         0         0         0    26.000
5 200400040    .214634   .000000  .000313   .019977   .000010    .061156
6 200400040          0         0         0         0         0          0
0 300700370                                                     1.00000 1.00000
1 300700370   538.000    67.000   942.000  3839.000    52.000    20.000 29076.000
2 300700370    .000207   .000072  .000107   .000057   .000002    .000001    .000013
3 300700370          0         0         0         0         0          0          0
4 300700370     3.000135951.000     6.000    35.000    15.000    20.000
5 300700370    .060418   .000003  .048653   .006791   .000010    .045663
6 300700370          0         0         0         0         0          0
0 300700380                                                     1.00000 1.00000
1 300700380   271.000     8.000   376.000   932.000         0  2272.000  3067.000
2 300700380    .000592   .000001  .000116   .000000   .000000    .000001    .000000
3 300700380          0         0         0         0         0          0          0
4 300700380     1.000  13129.000     7.000    19.000    10.000     6.000
5 300700380    .793427   .000014  .000010   .000010   .000010    .131118
6 300700380          0         0         0         0         0          0
0 300500390                                                     1.00000 1.00000
1 300500390   372.000         0   220.000  1917.000    13.000 10616.000 18000.000
2 300500390    .000115   .000001  .000110   .000079   .000002    .000003    .000042
3 300500390          0         0         0         0         0          0          0
4 300500390     1.000  39517.000    11.000    27.000     6.000     7.000
5 300500390    .020104   .000006  .000110   .025507   .000010    .011494
6 300500390          0         0         0         0         0          0
0 300600100                                                     1.00000 1.00000
1 300600100   429.000    97.000  1117.000   962.000 51543.000  7909.000  3639.000
2 300600100    .000000   .000001  .000137   .000012   .000002    .000001    .000000
3 300600100          0         0         0         0         0          0          0
4 300600100     2.000108711.000    16.000    26.000    19.000    25.000
5 300600100    .000010   .000004  .000010   .004030   .000010    .000010
6 300600100          0         0         0         0         0          0
0 300700110                                                     1.00000 1.00000
```

1	300700110	1152.000	2384.000	535.000	812.000	485398.000	7193.000	3400.000	
2	300700110	.000342	.000196	.000010	.000000	.000000	.000001	.000000	
3	300700110	0	0	0	0	0	0	0	
4	300700110	1.000	200352.000	8.000	50.000	7.000	15.000		
5	300700110	.000010	.000001	.109554	.000010	.000010	.000010		
6	300700110	0	0	0	0	0	0		
0	300700120						1.00000	1.00000	
1	300700120	369.000	4211.000	452.000	121.000	507321.000	6440.000	3247.000	
2	300700120	.000393	.000014	.000147	.000000	.000001	.000001	.000000	
3	300700120	0	0	0	0	0	0	0	
4	300700120	2.000	101556.000	10.000	34.000	17.000	15.000		
5	300700120	.000010	.000003	.066070	.000010	.000010	.000010		
6	300700120	0	0	0	0	0	0		
0	300600130						1.00000	1.00000	
1	300600130	438.000	681.000	831.000	2068.000	12939.000	39055.000	26900.000	
2	300600130	.000000	.000090	.000010	.000000	.000000	.000002	.000032	
3	300600130	0	0	0	0	0	0	0	
4	300600130	1.000	111947.000	9.000	32.000	23.000	12.000		
5	300600130	.000010	.000005	.008236	.011364	.000010	.000010		
6	300600130	0	0	0	0	0	0		
0	300700140						1.00000	1.00000	
1	300700140	701.000	434.000	660.000	2024.000	315704.000	17235.000	12011.000	
2	300700140	.000000	.000001	.000010	.000004	.000002	.000001	.000022	
3	300700140	0	0	0	0	0	0	0	
4	300700140	1.000	76122.000	11.000	40.000	3.000	17.000		
5	300700140	.000010	.000000	.011128	.000010	.009294	.038923		
6	300700140	0	0	0	0	0	0		
0	300700150						1.00000	1.00000	
1	300700150	966.000	3501.000	1149.000	1959.000	314163.000	7012.000	11738.000	
2	300700150	.000251	.000023	.000146	.000000	.000001	.000001	.000005	
3	300700150	0	0	0	0	0	0	0	
4	300700150	2.000	105348.000	11.000	34.000	23.000	15.000		
5	300700150	.069762	.000001	.034676	.000119	.000010	.030962		
6	300700150	0	0	0	0	0	0		
0	300700160						1.00000	1.00000	
1	300700160	957.000	43.000	1166.000	1236.000	616541.000	8327.000	10500.000	
2	300700160	.000160	.000001	.000010	.000012	.000001	.000001	.000000	
3	300700140	0	0	0	0	0	0	0	
4	300700150	2.000	231044.000	15.000	30.000	13.000	14.000		
5	300700160	.170696	.000001	.000010	.000010	.000010	.055477		
6	300700160	0	0	0	0	0	0		
0	300200170						.49013	.80792	
1	300200170	394.000	35.000	249.000	1709.000	54.000	13841.000	14968.000	
2	300200170	.000211	.000198	.000221	.000040	.000000	.000001	.000008	
3	300200170	0	0	0	0	0	0	0	
4	300200170	1.000	110779.000	6.000	23.000	12.000	7.000		
5	300200170	.144758	.000002	.092171	.000989	.005207	.027443		
6	300200170	0	0	0	0	0	0		
0	400600200						.51300	.87716	
1	400600200	659.000	214.000	1013.000	3843.000	3969.000	13057.000	9400.000	
2	400600200	.000018	.000068	.001104	.000019	.000000	.000000	.000007	
3	400600200	0	0	0	0	0	0	0	
4	400600200	2.000	68343.000	14.000	40.000	27.000	15.000		
5	400600200	.120416	.000002	.015018	.002389	.018418	.002001		
6	400600200	0	0	0	0	0	0		
0	500700210						1.00000	1.00000	
1	500700210	636.000	37.000	1182.000	2766.000	11.000	5089.000	2600.000	
2	500700210	.000363	.000232	.000455	.000073	.000002	.000001	.000000	
3	500700210	0	0	0	0	0	0	0	
4	500700210	1.000	24000.000	5.000	25.000	6.000	7.000		
5	500700210	.000010	.000005	.078135	.000010	.078965	.000010		
6	500700210	0	0	0	0	0	0		

0	500400220						1.00000	1.00000	
1	500400220	1608.000	2327.000	2062.000	2780.000	38209.000	33173.000	8704.000	
2	500400220	.000018	.000002	.000010	.000000	.000000	.000001	.000000	
3	500400220	0	0	0	0	0	0	0	0
4	500400220	5.00001	64626.000	10.000	112.000	14.000	31.000		
5	500400220	.179387	.000004	.012637	.000010	.000010	.007236		
6	500400220	0	0	0	0	0	0		
0	500600230						.70716	.70716	
1	500600230	3018.000	7143.000	5996.000	4479.000	87242.000	130380.000	27339.000	
2	500600230	.000000	.000001	.000045	.000000	.000000	.000001	.000000	
3	500600230	1968.900	985.043	0	13237.114	79297.377	.189E+07	5953.826	
4	500600230	6.00002	75308.000	31.000	69.000	97.000	35.000		
5	500600230	.049036	.000003	.002747	.001419	.000010	.000010		
6	500600230	0	0	0	0	230.317	9.888		
0	500600240						.57660	.68262	
1	500600240	964.000	223.000	805.000	1291.000	21518.000	62124.000	12988.000	
2	500600240	.000045	.000036	.000055	.000004	.000000	.000001	.000015	
3	500600240	0	0	0	0	0	0	0	0
4	500600240	2.00001	35372.000	22.000	43.000	17.000	25.000		
5	500600240	.093818	.000004	.006394	.004102	0	.012130		
6	500600240	0	0	0	0	15.463	0		
0	500300250						1.00000	1.00000	
1	500300250	115.000	31.000	670.000	469.000	1300.000	10329.000	11089.000	
2	500300250	.000178	.000001	.000121	.000000	.000000	.000004	.000033	
3	500300250	0	0	0	0	0	0	0	0
4	500300250	1.000	38560.000	6.000	35.000	3.000	8.000		
5	500300250	.487952	.000012	.049462	.033483	.038284	.000010		
6	500300250	0	0	0	0	0	0		
0	600200300						1.00000	1.00000	
1	600200300	423.000	2271.000	973.000	1313.000	60148.000	12273.000	24391.000	
2	600200300	.000000	.000194	.000018	.000050	.000001	.000001	.000016	
3	600200300	0	0	0	0	0	0	0	0
4	600200300	1.00001	36531.000	13.000	36.000	1.000	12.000		
5	600200300	.000010	.000007	.018485	.000013	.043490	.000010		
6	600200300	0	0	0	0	0	0		
0	600600310						.67728	.71226	
1	600600310	295.000	135.000	1558.000	1785.000	97500.000	24353.000	16950.000	
2	600600310	0	.000068	.000170	.000044	.000001	.000000	.000005	
3	600600310	319.495	0	0	0	0	0	0	0
4	600600310	2.00001	66190.000	13.000	50.000	15.000	25.000		
5	600600310	.085590	.000000	.000617	.001546	.009951	.048675		
6	600600310	0	0	0	0	0	0		
0	600600320						.54864	.54864	
1	600600320	592.000	428.000	946.000	1357.000	16284.000	16002.000	6278.000	
2	600600320	.000371	.000056	.000217	.000006	.000001	.000001	.000004	
3	600600320	0	0	0	0	0	0	0	0
4	600600320	1.00001	13001.000	8.000	43.000	8.000	24.000		
5	600600320	.045723	.000002	.063758	.000689	.024676	.006212		
6	600600320	0	0	0	0	0	0		
0	600600330						.54037	.75373	
1	600600330	412.000	174.000	376.000	1492.000	74556.000	5165.000	5221.000	
2	600600330	.000200	.000027	0	0	.000001	0	.000003	
3	600600330	0	0	373.279	1750.541	0	14303.698	0	
4	600600330	1.000	38393.000	9.000	29.000	23.000	16.000		
5	600600330	.341173	.000009	.005887	0	0	.037674		
6	600600330	0	0	0	10.620	5.361	0		
0	600700340						.49499	.60591	
1	600700340	436.000	455.000	1072.000	1112.000	56878.000	9216.000	11250.000	
2	600700340	.000009	.000052	.000130	.000043	.000001	.000001	.000010	
3	600700340	0	0	0	0	0	0	0	0
4	600700340	1.00001	33872.000	12.000	29.000	22.000	21.000		
5	600700340	.123716	.000002	0	.005658	.015016	.030932		

6	6007C0340	0	0	.718	0	0	0		
0	6006C0350						1.00000	1.00000	
1	6006C0350	276.000	682.000	2895.000	959.000	12666.000	7333.000	9852.000	
2	6006C0350	.000452	.000001	.000294	.000016	.000000	.000001	.000000	
3	6006C0350	0	0	0	0	0	0	0	
4	6006C0350	1.000	169792.000	6.000	30.000	5.000	13.000		
5	6006C0350	.000010	.000000	.065613	.000010	.011669	.000285		
6	6006C0350	0	0	0	0	0	0		
0	6006C0360						1.00000	1.00000	
1	6006C0360	971.000	337.000	869.000	1639.000	230032.000	95911.000	7000.000	
2	6006C0360	.000423	.000001	.000010	.000000	.000002	.000002	.000000	
3	6006C0360	0	0	0	0	0	0	0	
4	6006C0360	1.000	72357.000	16.000	37.000	13.000	12.000		
5	6006C0360	.000010	.000005	.003312	.015154	.000010	.000010		
6	6006C0360	0	0	0	0	0	0		
0	6006C0370						.46016	.58693	
1	6006C0370	393.000	358.000	344.000	478.000	134878.000	9121.000	6849.000	
2	6006C0370	.000046	.000001	.000376	.000024	.000001	.000001	.000005	
3	6006C0370	0	0	0	0	0	0	0	
4	6006C0370	2.000	142789.000	12.000	36.000	24.000	17.000		
5	6006C0370	.129033	.000002	.004441	.004256	.012485	.008114		
6	6006C0370	0	0	0	0	0	0		
0	6007C0380						1.00000	1.00000	
1	6007C0380	1355.000	643.000	1740.000	2227.000	222000.000	23124.000	16064.000	
2	6007C0380	.000194	.000001	.000029	.000000	.000001	.000001	.000002	
3	6007C0380	0	0	0	0	0	0	0	
4	6007C0380	5.000	279769.000	9.000	33.000	11.000	19.000		
5	6007C0380	.102152	.000002	.018934	.005372	.000010	.000010		
6	6007C0380	0	0	0	0	0	0		
0	6004C0390						.54844	.90707	
1	6004C0390	1301.000	736.000	2092.000	810.000	25496.000	7102.000	8678.000	
2	6004C0390	.000006	.000371	.000097	.000026	.000001	.000001	.000013	
3	6004C0390	0	0	0	0	0	0	0	
4	6004C0390	1.000	88923.000	16.000	40.000	13.000	11.000		
5	6004C0390	.134053	.000004	.013282	.005515	.019034	0		
6	6004C0390	0	0	0	0	0	1.536		
0	7004C0400						1.00000	1.00000	
1	7004C0400	562.000	1459.000	1472.000	1341.000	18250.000	15634.000	11651.000	
2	7004C0400	.000219	.000001	.000023	.000000	.000000	.000002	.000003	
3	7004C0400	0	0	0	0	0	0	0	
4	7004C0400	3.000	57372.000	20.000	39.000	10.000	16.000		
5	7004C0400	.261083	.000004	.009216	.014219	.002733	.000010		
6	7004C0400	0	0	0	0	0	0		
0	7004C0410						.82956	.88555	
1	7004C0410	532.000	1579.000	1745.000	1935.000	14100.000	12592.000	12301.000	
2	7004C0410	.000068	.000122	.000139	.000024	.000000	.000001	.000005	
3	7004C0410	0	0	0	0	0	0	0	
4	7004C0410	2.000	171399.000	9.000	40.000	26.000	19.000		
5	7004C0410	.102959	.000001	.043822	.001631	.006737	.014413		
6	7004C0410	0	0	0	0	0	0		
0	7003C0420						1.00000	1.00000	
1	7003C0420	820.000	682.000	862.000	1502.000	38639.000	45850.000	7846.000	
2	7003C0420	.000359	.000043	.000013	.000000	.000001	.000002	.000005	
3	7003C0420	0	0	0	0	0	0	0	
4	7003C0420	2.000	101600.000	16.000	16.000	10.000	13.000		
5	7003C0420	.242334	.000004	.000010	.026771	.015278	.000010		
6	7003C0420	0	0	0	0	0	0		
0	7005C0430						.67099	.98074	
1	7005C0430	805.000	542.000	1647.000	2270.000	19945.000	14258.000	9196.000	
2	7005C0430	.000288	.000062	.000169	.000011	.000001	.000001	.000003	
3	7005C0430	0	0	0	0	0	0	0	
4	7005C0430	1.000	74899.000	7.000	22.000	35.000	15.000		

5	700500430	.035201	.000001	.060502	.000672	.010437	.007010	
6	700500430	0	0	0	0	0	0	
0	700200440						1.00000	1.00000
1	700200440	530.000	1512.000	1076.000	3335.000	46500.000	23686.000	1100.000
2	700200440	.000174	.000122	.000310	.000026	.000000	.000001	.000000
3	700200440	0	0	0	0	0	0	0
4	700200440	1.00002	21593.000	10.000	28.000	2.000	13.000	
5	700200440	.000010	.000003	.000010	.013654	.000010	.000010	
6	700200440	0	0	0	0	0	0	
0	700500450						1.00000	1.00000
1	700500450	231.000	25.000	952.000	1096.000	800.000	7388.000	4346.000
2	700500450	.000215	.000001	.000191	.000000	.000000	.000003	.000005
3	700500450	0	0	0	0	0	0	0
4	700500450	2.000	64750.000	5.000	29.000	14.000	9.000	
5	700500450	.367761	.000006	.070770	.009035	.000010	.000010	
6	700500450	0	0	0	0	0	0	
0	700200460						1.00000	1.00000
1	700200460	523.000	2639.000	1937.000	1644.000	38980.000	18879.000	9986.000
2	700200460	.000118	.000325	.000310	.000005	.000000	.000001	.000003
3	700200460	0	0	0	0	0	0	0
4	700200460	1.00001	38392.000	10.000	23.000	23.000	12.000	
5	700200460	.000010	.000090	.000010	.038366	.000010	.008619	
6	700200460	0	0	0	0	0	0	
0	700200470						1.00000	1.00000
1	700200470	323.000	1019.000	1934.000	1666.000	29219.000	12650.000	8813.000
2	700200470	.000000	.000047	.000141	.000000	.000001	.000002	.000003
3	700200470	0	0	0	0	0	0	0
4	700200470	2.000	65200.000	11.000	26.000	25.000	13.000	
5	700200470	.322698	.000007	.033716	.004963	.000746	.000010	
6	700200470	0	0	0	0	0	0	
0	700400480						.66644	.66644
1	700400480	673.000	155.000	1491.000	2319.000	20894.000	9371.000	6507.000
2	700400480	.000356	.000001	.000211	.000024	.000001	.000001	.000004
3	700400480	0	0	0	0	0	0	0
4	700400480	1.00001	10838.000	9.000	37.000	10.000	12.000	
5	700400480	.017747	.000000	.036381	.000577	.009204	.845457	
6	700400480	0	0	0	0	0	0	
0	700200490						.59317	.74958
1	700200490	588.000	480.000	2409.000	1551.000	77631.000	14046.000	10813.000
2	700200490	.000056	.000048	.000138	.000035	.000001	.000000	.000004
3	700200490	0	0	0	0	0	0	0
4	700200490	1.00015	1467.000	10.000	28.000	21.000	15.000	
5	700200490	.038938	.000001	.012256	.001946	.022714	.013666	
6	700200490	0	0	0	0	0	0	
0	700200510						.50039	.76143
1	700200510	283.000	415.000	576.000	1356.000	59586.000	9271.000	4658.000
2	700200510	.000085	.000014	.000096	.000046	.000001	.000001	.000011
3	700200510	0	0	0	0	0	0	0
4	700200510	1.000	63500.000	6.000	15.000	21.000	12.000	
5	700200510	.211601	.000004	.004603	.011086	.021289	.007813	
6	700200510	0	0	0	0	0	0	
0	700600520						.73909	.90669
1	700600520	549.000	2107.000	1120.000	1634.000	90748.000	3713.000	7401.000
2	700600520	.000102	.000121	.000174	.000036	.000000	.000001	.000006
3	700600520	0	0	0	0	0	0	0
4	700600520	1.000	91334.000	3.000	26.000	28.000	14.000	
5	700600520	.095863	.000091	.047739	.002994	.005412	.020497	
6	700600520	0	0	0	0	0	0	
0	700200530						1.00000	1.00000
1	700200530	668.000	1246.000	2463.000	4540.000	62106.000	71149.000	9500.000
2	700200530	.000367	.000001	.000228	.000013	.000000	.000001	.000005
3	700200530	0	0	0	0	0	0	0

4	700200530	1.0001	99405.000	7.000	45.000	10.000	24.000		
5	700200530	.000010	.000000	.055406	.000010	.000010	.040834		
6	700200530	0	0	0	0	0	0		
0	700200540						.44634	.55918	
1	700200540	235.000	194.000	998.000	955.000	13452.000	10021.000	7019.000	
2	700200540	0	.000057	.000154	.000001	0	.000001	.000011	
3	700200540	29.157	0	0	0	53101.733	0	0	
4	700200540	1.000	75100.000	9.000	21.000	24.000	12.000		
5	700200540	.193478	.000004	.021780	.000986	.014089	.012171		
6	700200540	0	0	0	0	0	0		
0	700700550						.63301	.67861	
1	700700550	878.000	1081.000	744.000	1353.000	96272.000	11894.000	10334.000	
2	700700550	.000337	.000022	.000187	.000032	.000001	.000000	.000004	
3	700700550	0	0	0	0	0	0	0	
4	700700550	1.0001	74726.000	8.000	40.000	11.000	13.000		
5	700700550	.084215	.000000	.039493	.003173	.022934	.018528		
6	700700550	0	0	0	0	0	0		
0	700100560						.69906	.71078	
1	700100560	163.000	1425.000	1579.000	565.000	59961.000	23629.000	7722.000	
2	700100560	.000008	.000079	.000113	.000002	.000001	.000002	.000022	
3	700100560	0	0	0	0	0	0	0	
4	700100560	1.000	80340.000	11.000	25.000	31.000	14.000		
5	700100560	.126268	.000006	.009181	.002769	0	.023565		
6	700100560	0	0	0	0	.884	0		
0	700700570						.70317	.94919	
1	700700570	934.000	824.000	925.000	2531.000	106550.000	25809.000	6107.000	
2	700700570	.000324	.000070	.000191	.000013	.000001	.000001	.000004	
3	700700570	0	0	0	0	0	0	0	
4	700700570	1.0001	05043.000	6.000	25.000	25.000	16.000		
5	700700570	.039658	.000001	.068163	.000757	.011759	.007897		
6	700700570	0	0	0	0	0	0		
0	700200590						.37655	.68892	
1	700200590	614.000	980.000	535.000	2769.000	33271.000	14259.000	14032.000	
2	700200590	.000343	.000064	0	.000024	.000000	.000000	.000006	
3	700200590	0	0	933.336	0	0	0	0	
4	700200590	1.0001	54181.000	7.000	26.000	26.000	13.000		
5	700200590	.128407	.000001	.011386	0	.020997	.017907		
6	700200590	0	0	0	5.667	0	0		
0	700200600						1.00000	1.00000	
1	700200600	893.000	171.000	1980.000	3756.000	54058.000	23743.000	49347.000	
2	700200600	.000070	.000001	.000010	.000000	.000000	.000001	.000019	
3	700200600	0	0	0	0	0	0	0	
4	700200600	2.0001	79573.000	8.000	60.000	9.000	25.000		
5	700200600	.000010	.000004	.004243	.000010	.020440	.000010		
6	700200600	0	0	0	0	0	0		
0	900600610						.52847	.70674	
1	900600610	1095.000	574.000	1083.000	1360.000	45342.000	13539.000	10871.000	
2	900600610	.000014	.000059	.000092	.000044	.000000	.000001	.000015	
3	900600610	0	0	0	0	0	0	0	
4	900600610	1.000	66400.000	15.000	36.000	15.000	17.000		
5	900600610	.131924	.000003	0	.008910	.017293	.013981		
6	900600610	0	0	.102	0	0	0		
0	900600620						1.00000	1.00000	
1	900600620	1981.000	797.000	494.000	1294.000	27889.000	6257.000	8318.000	
2	900600620	.000422	.000015	.000228	.000000	.000001	.000001	.000000	
3	900600620	0	0	0	0	0	0	0	
4	900600620	1.0001	46011.000	7.000	39.000	9.000	12.000		
5	900600620	.000010	.000000	.035720	.000010	.000010	.061240		
6	900600620	0	0	0	0	0	0		
0	900600630						.33539	.95237	
1	900600630	758.000	4703.000	403.000	1730.000	74607.000	11127.000	23329.000	
2	900600630	.000017	.000012	0	.000011	.000000	.000000	.000006	

3	900600630	0	0	404.349	0	0	0	0	
4	900600630	1.000	617986.000	13.000	42.000	4.000	15.000		
5	900600630	.066333	.000001	.000618	.002316	.009382	.005164		
6	900600630	0	0	0	0	0	0		
0	900600650						1.00000	1.00000	
1	900600650	1871.000	2334.000	1786.000	1768.000	55730.000	279174.000	12337.000	
2	900600650	.000294	.000013	.000010	.000000	.000000	.000001	.000010	
3	900600650	0	0	0	0	0	0	0	
4	900600650	2.000	135750.000	18.000	45.000	5.000	15.000		
5	900600650	.000010	.000002	.031105	.000010	.015708	.004211		
6	900600650	0	0	0	0	0	0		
0	900700660						1.00000	1.00000	
1	900700660	944.000	714.000	4495.000	1045.000	67467.000	6758.000	10800.000	
2	900700660	.000297	.000039	.000143	.000000	.000000	.000001	.000000	
3	900700660	0	0	0	0	0	0	0	
4	900700660	1.000	76314.000	14.000	9.000	19.000	18.000		
5	900700660	.000010	.000002	.062401	.000010	.000010	.000010		
6	900700660	0	0	0	0	0	0		
0	900600670						1.00000	1.00000	
1	900600670	3095.000	1078.000	388.000	2002.000	148913.000	16074.000	12780.000	
2	900600670	.000261	.000001	.000010	.000000	.000000	.000001	.000011	
3	900600670	0	0	0	0	0	0	0	
4	900600670	2.000	156023.000	17.000	43.000	10.000	16.000		
5	900600670	.000010	.000002	.000010	.000010	.000010	.045328		
6	900600670	0	0	0	0	0	0		
0	900500690						1.00000	1.00000	
1	900500690	2291.000	4466.000	1406.000	2376.000	188000.000	20339.000	40000.000	
2	900500690	.000091	.000034	.000010	.000000	.000000	.000001	.000015	
3	900500690	0	0	0	0	0	0	0	
4	900500690	2.000	195035.000	17.000	54.000	13.000	18.000		
5	900500690	.000013	.000003	.013730	.002558	.000010	.000010		
6	900500690	0	0	0	0	0	0		
0	900600700						.60687	.83235	
1	900600700	1225.000	821.000	1762.000	2412.000	130000.000	12817.000	10651.000	
2	900600700	.000175	.000083	.000028	.000035	.000000	.000000	0	
3	900600700	0	0	0	0	0	0	69810.022	
4	900600700	2.000	847630.000	11.000	24.000	8.000	14.000		
5	900600700	.077898	.000001	0	.013087	.004648	.013087		
6	900600700	0	0	13.614	0	0	0		
0	900600710						1.00000	1.00000	
1	900600710	993.000	2271.000	1177.000	783.000	3600.000	6176.000	6202.000	
2	900600710	.000996	.000001	.000010	.000000	.000000	.000001	.000000	
3	900600710	0	0	0	0	0	0	0	
4	900600710	1.000	0	9.000	61.000	10.000	15.000		
5	900600710	.000010	.999905	.000010	.000010	.000010	.000010		
6	900600710	0	0	0	0	0	0		
0	900700720						.60174	.70955	
1	900700720	147.000	14.000	510.000	293.000	877.000	0	350.000	
2	900700720	0	0	.000329	.000042	.000002	.000003	.000007	
3	900700720	351.086	322.102	0	0	0	0	0	
4	900700720	1.000	40441.000	3.000	10.000	10.000	7.000		
5	900700720	.417771	.000007	.117904	.006649	0	0		
6	900700720	0	0	0	0	3.319	2.658		
0	900500730						1.00000	1.00000	
1	900500730	1194.000	1145.000	716.000	2567.000	3659.000	11590.000	10824.000	
2	900500730	.000000	.000001	.000010	.000367	.000000	.000001	.000000	
3	900500730	0	0	0	0	0	0	0	
4	900500730	1.000	190.000	18.000	32.000	5.000	14.000		
5	900500730	.000010	.002262	.031647	.000010	.000010	.000010		
6	900500730	0	0	0	0	0	0		
0	900700640						.65618	.98060	
1	900700640	2171.000	5377.000	3416.000	2989.000	199000.000	16708.000	6040.000	

2	900700640	.000175	.000000	.000313	0	.000001	.000001	.000006
3	900700640	0	0	0	4588.943	0	0	0
4	900700640	2.000231	708.000	17.000	43.000	36.000	30.000	
5	900700640	.010505	.000002	.006188	.005806	.002104	.003040	
6	900700640	0	0	0	0	0	0	

Appendix L: Constrained Facet Analysis Lambda File

1200200010	700400400	1.01900
2200200010	700200440	.08568
3200200010	900600710	1.22336
4200200010	300500090	1.31246
5200200010	900500730	-.99500
6200200010	700200600	.54179
7200200010	500300250	-5.00882
8200200010	300700070	.39762
9200200010	200700020	.60978
1300200170	300700070	.34364
2300200170	200400040	-.04671
3300200170	700200600	.03139
4300200170	700200440	.04657
5300200170	900500690	.01042
6300200170	700200530	-.05781
7300200170	300700120	-.47274
8300200170	500400220	-.03656
9300200170	600700380	.03158
10300200170	200500030	-.06321
11300200170	300700150	.80329
12300200170	500600230	-.08661
1400600200	200700020	.43161
2400600200	200500030	.26171
3400600200	900700660	.21204
4400600200	700400400	.12340
5400600200	500400220	-.01953
6400600200	200400040	-.07834
7400600200	900500690	-.16181
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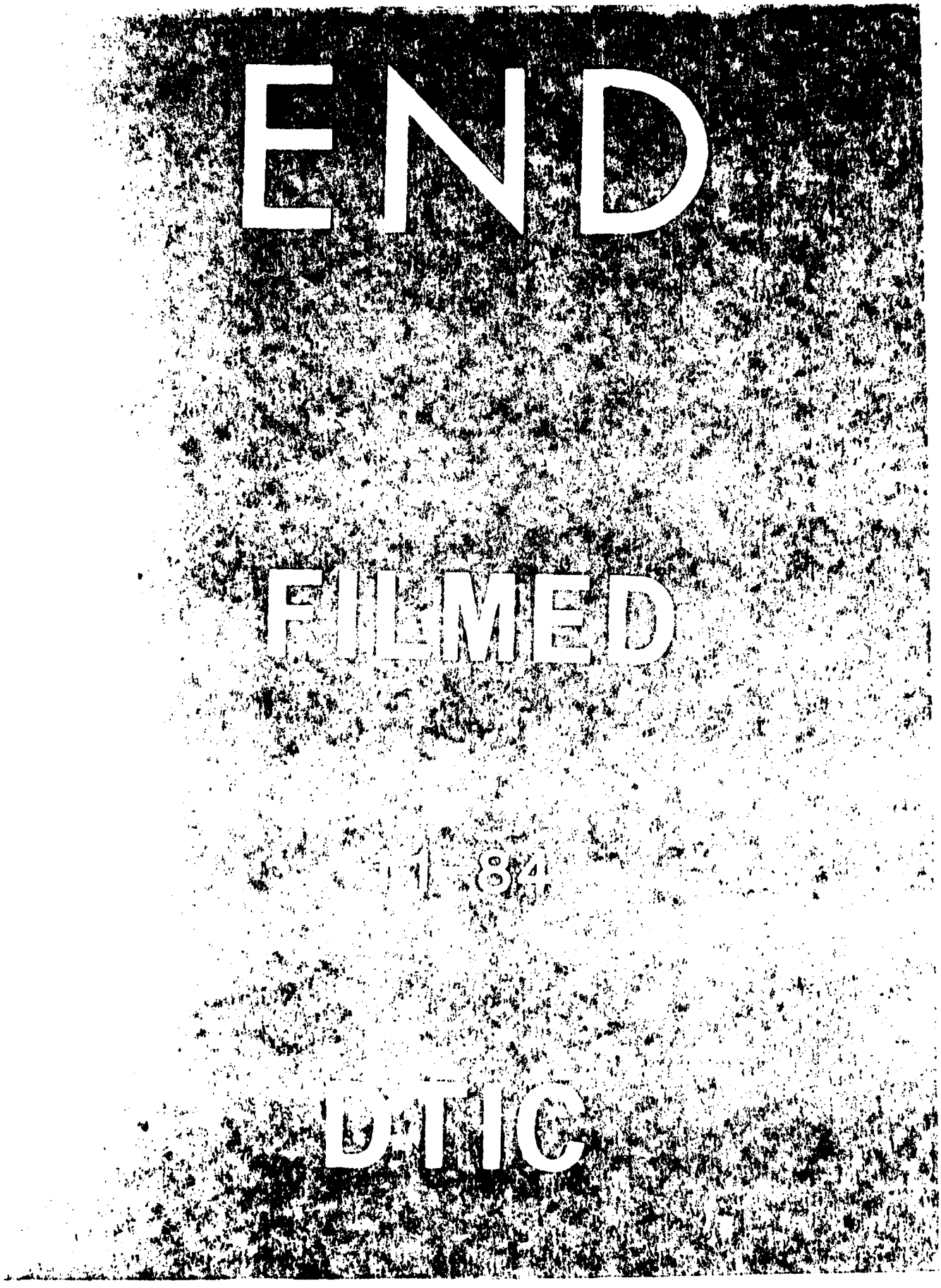
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